THE SCIENCE OF COMMON THINGS

TOWER
AND
LUNT

General Science is a live subject. It awakens the interest of the pupil

THE SCIENCE OF COMMON THINGS

A Textbook of General Science

BY

SAMUEL F. TOWER

HEAD MASTER OF SOUTH BOSTON HIGH SCHOOL, BOSTON
FORMERLY HEAD OF SCIENCE DEPARTMENT
ENGLISH HIGH SCHOOL, BOSTON

AND

JOSEPH R. LUNT

TEACHER OF GENERAL SCIENCE
ENGLISH HIGH SCHOOL, BOSTON
LECTURER ON METHODS OF TEACHING GENERAL SCIENCE

D. C. HEATH & CO., PUBLISHERS
BOSTON NEW YORK CHICAGO

COPYRIGHT, 1922,
BY D. C. HEATH & CO.

2 D 6

PRINTED IN U.S.A.

FOREWORD TO THE TEACHER

We hope that The Science of Common Things will prove to be a practical, teachable textbook of General Science. It represents the fruits of over ten years of specialization in the organizing and teaching of General Science courses in High and Junior High Schools.

We have deemed it inadvisable to attempt to cover the entire field of Science. The work as outlined in this book deals solely with the immediate environment of the pupil — with things that happen every day in his experience. The selection of each teaching unit has been made solely on the basis of *direct and universal value.* Can the pupil translate the knowledge and experience acquired into actual service for his own welfare?

The project-problem method is used throughout the book. Each project is developed by a series of closely knit problems, arranged carefully, to bring out the scientific principles involved. There are approximately 250 problems in all. This total includes about 150 class problems and 100 home problems.

At the end of each chapter, a concise, non-technical summary is given, written in a style and language that should appeal to boys and girls. The informational part of each chapter is removed as far as possible from the experimental or development part. This plan helps to stimulate interest and self-activity on the part of the pupil. The pupil becomes an active participant in the solving of problems. He is given an opportunity to exercise and train his own powers of observing and reasoning.

Each experiment is outlined with great care, and definite directions are given in detail in regard to the use of materials and the handling of apparatus. No previous experience is assumed. Most of the experiments can be performed without difficulty by the boys or girls themselves.

The development of the problems depends upon thought-provoking questions. These are intended to arouse a state of alert interest, and to bring out vividly the fundamental ideas involved. We advise teachers to take up the questions in order, for they follow one another in natural sequence.

The equipment needed to teach this book has been standardized, with due regard to school and classroom limitations. Of the many problems and experiments given, all but twelve, or over 95 per cent, can be performed in an ordinary classroom, *without running water, electricity, or illuminating gas.* For schools not supplied with illuminating gas, a special and satisfactory equipment is recommended. (See Equipment, page 388.)

We wish to acknowledge our indebtedness to Miss Lillian J. MacRae of the South Boston High School, who has read the entire manuscript; and to Professor S. C. Prescott of the Massachusetts Institute of Technology, who has read the chapter entitled "The World of Little Things." We are grateful to both of these teachers for many helpful suggestions.

We are grateful, also, to Dr. J. Homer Wright, to Dr. William H. Smith, and to Dr. H. F. Hartwell, of the Massachusetts General Hospital. Through their kindness we are able to use as illustrations the exceptionally fine micro-photographs of bacteria which are shown in Chapter X.

In the preparation of our illustrations a large number of boys and girls very kindly and patiently served us as models. To all of these, whether or not their pictures were selected for printing, we offer our hearty thanks.

Finally, we wish to express our indebtedness to the thousands of pupils who have sat in our classes. By their enthusiasm, their interest, and their natural reactions to the problems that were presented to them, they have unconsciously been coworkers in the making of this book.

SAMUEL F. TOWER
JOSEPH R. LUNT

BOSTON, *May, 1922.*

CONTENTS

CHAPTER		PAGE
I.	The Air We Breathe	1
II.	The Food We Eat	23
III.	The Water We Drink	59
IV.	Weather and Its Changes	107
V.	A Study of Fire	145
VI.	How We Heat Our Homes	182
VII.	How We Light Our Homes	219
VIII.	Electricity in Our Homes	259
IX.	The Clothes We Wear	305
X.	The World of Little Things	334
	Individual Projects	377
	General Science Library	380
	Equipment	383
	Index	393

To the Boys and Girls Who Study This Book:

The *Science of Common Things* gives you many interesting and worth-while experiments about matters directly connected with your daily life, so that you will have a better understanding of what is going on about you. We want you to learn to observe closely, to think carefully, and to draw natural conclusions from the results of your experiments. If you succeed in gaining these habits, you will be happier and much more successful all through life.

This book is written for you. We want you to be the scientist; to conduct the experiments, and to find out the correct answers to the questions. The work of each chapter is divided into so-called projects. Each of these is a scientific investigation for you to carry on. To make this investigation easier for you, we have divided many of the projects into simpler problems. Take these up one after another; for they are arranged in order, very carefully. *Do not omit the home problems.* Watch each experiment closely, to see what happens. Don't jump at conclusions. Think before you answer. Be sure to take notes, and write up the results of your experiments carefully and neatly each day.

THE SCIENCE OF COMMON THINGS

CHAPTER I

THE AIR WE BREATHE

Air is invisible. For this reason, we are not always aware of its presence about us or the many blessings it contributes to our daily lives. What would happen if the great ocean of air surrounding our earth should suddenly disappear? Winds would stop blowing. There would be no fires to keep us warm or cook our food. A calamity even worse than these would befall us. For with no air to breathe, every living thing including man would soon die. The earth would become a barren, lifeless desert, glistening in the sun's rays like a great moon.

In this chapter we want you to perform some interesting experiments on air to show what it is, what it is made of, how to use it, and how it affects our daily lives.

PROJECT I

IS AIR A REAL SUBSTANCE?

Problems — 1. Does air occupy space?
2. Does air weigh anything?

Problem 1 — Does air occupy space?

Home Problem. — (*a*) Fill a dish pan with water. Float a cork on the surface. Invert a drinking glass and bring the mouth down over the cork. Push it to the bottom of the water in the dish pan. Repeat several times. *What happens?*

Watch the cork as you press the jar down

(*b*) Take an "empty" bottle. Invert it. Push the mouth of the bottle down into the water in the dish pan. Does water enter the bottle? Why? Repeat, tipping

the bottle to one side. What happens? Fill the bottle, holding it under water. What are the bubbles? Where do they come from? Why is it necessary to tip the bottle in order to fill it with water?

Class Problem. — Push a two-hole rubber stopper into the mouth of an Erlenmeyer flask. Through one hole push the end of a thistle tube. Hold a finger over the other hole. Pour water into the mouth of the thistle tube. *What happens?* Remove the finger. Again pour water into the mouth of the thistle tube. *What happens?* How do you account for this?

Problem 2 — Does air weigh anything?

Class Problem. — Suspend a balance from a support. Hang an empty football bladder from one arm of the balance. From the other arm hang a small box. Pour fine sand into the box until it just balances the football bladder. With a small pump fill the bladder with air. Again hang it from the arm of the balance. *What happens?*

What makes the bladder go down?

Balance again with sand. Now let the air escape. What is the result? *Does air weigh anything?*

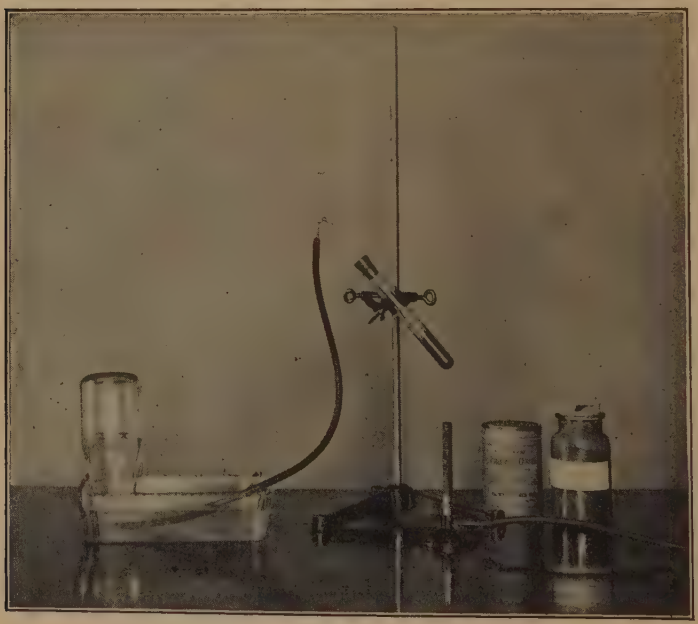
PROJECT II

WHAT IS AIR COMPOSED OF?

Problems — 1. A study of oxygen.
2. What a jar full of air contains.
3. A study of carbon dioxide.

Problem 1 — A study of oxygen

Class Problem. — Into a test tube put an even teaspoonful of *potassium chlorate.* Add one-fourth teaspoonful



Watch the bubbles. Where do they come from?

of *manganese dioxide.* Mix thoroughly by shaking. Push a one-hole rubber stopper into the mouth of the test tube. Bend a short piece of glass tubing at right angles. Push

one end into the hole in the stopper. Over the other end slip a piece of rubber tubing. Let this extend into a basin partly filled with water.

Fill two pint jars with water. Stand them inverted in the basin. Hold the end of the rubber tubing under water.

Now heat the chemicals in the test tube slowly. Let the first few bubbles escape. Why? Now slip the end of the rubber tubing under one of the jars, taking care not to pinch it.

What are the bubbles? Where do they come from? Why is water forced out of the jar? Fill the second jar in the same way.

Both jars are now filled with a gas called *oxygen*. Slip a piece of cardboard under one of the jars and set it upright on the table. What color is oxygen? Ignite a splint of wood. Blow out the flame. Thrust the spark into the jar. Repeat several times. *What happens?* Does oxygen burn? How does oxygen affect the burning of the splint? What does this prove?

Pull out a single strand of iron picture cord wire. Make a small loop in one end. Pick up a little powdered sulphur with the loop. Ignite it. Thrust it into the second jar of oxygen. *What happens?* Does iron burn in air? Which supports combustion better, air or oxygen? Why?

Problem 2 — What a jar full of air contains

Class Problem. — Take a quart preserve jar with a wire clamp fastening, and two new rubber rings. Grease the rings on both sides and put them on the jar. Cut off a piece of yellow phosphorus, the size of a kidney bean. (*Caution.* — Cut phosphorus under water. Do not touch it with the hands.)

Dry the phosphorus with a piece of blotting paper, taking care to avoid pressure or friction. Place it in the tin cover of a small baking-powder can. Set the tin cover in the center of the glass cover of the preserve jar. Invert the jar and fit it to the glass cover. Clamp it down tight with the wire fastening. Partly fill a bowl or basin with hot water. Hold the end of the inverted jar in the hot water for a short time. *What happens?*

Fit the jar to the cover with care

Watch the phosphorus burn. What supports the burning of the phosphorus? Why does the fire go out after a few moments? Does all the phosphorus burn? How do you account for this?

Let the jar cool for at least ten minutes. Invert it and plunge the top under water in a basin. With a knife pry off the cover, taking care to keep it under water all the time. Do not tilt the jar. Slip a piece of cardboard under the mouth of the jar, and press it firmly with the fingers. With a quick movement, set the jar upright on the table.

Notice the water in the jar. Where did it come from? Why did it rise in the jar? What was taken out of the air when the phosphorus burned? What happened to this oxygen? What happened to the phosphorus that was burned? Could they escape from the jar? How was the white smoke formed? *What gases are left in the jar?* Ex-

amine the gases above the water in the jar. What color are they? Plunge a blazing splint of wood into the jar. *What happens?* Do the gases burn? Do they support combustion? *Nitrogen is the principal gas present in the jar.*

Don't drop the jar when the phosphorus starts to burn

Estimate approximately the percentage of oxygen and nitrogen in air as follows: Pour the water from the jar into a graduate marked off in cubic centimeters. How many cubic centimeters of water are there? How many cubic centimeters of oxygen did the jar full of air contain? Find out how many cubic centimeters of water the jar holds. From this, estimate the number of cubic centimeters of nitrogen the jar full of air contained. Estimate the percentage of oxygen in air. Of nitrogen.

Problem 3 — A study of carbon dioxide

Class Problem. — Take a small bottle with a wide mouth. Into this drop 6 or 8 small marble chips. Barely cover with water. Fit a two-hole rubber stopper into the mouth of the bottle. Through one hole push a thistle tube, so that the end is submerged in the water. Bend a short piece of glass tubing at right angles. Push one end through the second hole in the rubber stopper. Over the other end

Pour the acid in slowly, a few drops at a time

slip a piece of rubber tubing. Let this extend into a basin partly filled with water.

Fill three pint jars with water and invert them into the water in the basin. Pour hydrochloric acid down the thistle tube, a few drops at a time. Hold the end of the rubber tubing under water, and let the first few bubbles escape. Why? Now slip the tubing under one of the jars. What are the bubbles? Where do they come from?

Why is water pushed out of the jar? Fill the other two jars in the same way.

The jars are now filled with a gas called *carbon dioxide.* Slip a piece of cardboard under one of the jars and set it upright on the table. What color is the gas? Remove the cardboard and thrust a burning splint into the jar. *What happens?* Repeat several times. Does carbon dioxide burn? Does it help other things to burn?

Ignite a large wooden splint. Let it burn for a few moments. Blow out the flame. Thrust it into the second jar of carbon dioxide. Repeat several times until the jar is well filled with smoke. Hold the jar right side up. *What happens?* Now invert the jar. *What happens?* Which is heavier, carbon dioxide or air? Into the third jar pour half an inch of clear lime water. Shake it up. *What happens?* Carbon dioxide changes clear lime water to a milky color. Hence lime water is used as a test for its presence.

Does air contain carbon dioxide? Pour about six inches of clear lime water into a tall cylindrical graduate. With a bicycle pump force air through this lime water for 15 or 20 minutes. *What happens?* What does this prove? Why is it necessary to force air through the lime water for so long a time before it changes to a milky color? What does this show concerning the quantity of carbon dioxide in the air? Where does the carbon dioxide in the air come from?

PROJECT III

A STUDY OF BREATHING

Problems — 1. The air we breathe out.
2. The quantity of air we breathe.
3. How to test the air capacity of the lungs.

Problem 1 — The air we breathe out

Home Problem. — Breathe on a cold mirror for a few moments. What happens? What is this substance? Where does it come from? Show from this how breathing affects the air of a room.

How long will the candle burn?

Class Problem. — (*a*) Select a quart milk bottle. Light a candle. Lower it into the bottle with a piece of wire. Cover the top with a cardboard. With a watch, time the number of seconds the candle burns. Pour half an inch of clear lime water into the bottle and shake. *What happens?* What does this show? Where does this carbon dioxide come from? How was it formed in the bottle?

(*b*) Fill the milk bottle with water. Invert it into a basin partly filled with water. Put one end of a rubber tube under the mouth of the bottle. Blow through the other end. Fill the bottle with air from the lungs. Pour half an inch of clear lime water into the

bottle and shake. *What happens?* What does this prove? Where does the carbon dioxide come from? How is it formed in the body?

(*c*) Refill the milk bottle with air from the lungs. Light the candle. Lower it into the bottle. Cover the top with a cardboard. With a watch, time the number of seconds the candle burns. How many seconds did the candle burn in the bottle of fresh air? How do you account for this difference in time?

Problem 2 — The quantity of air we breathe

Class Problem. — Fill a gallon bottle with water. Invert it into a large basin partly filled with water. Slip one end of a rubber tubing into the mouth of the bottle. Inhale naturally. Exhale, blowing the air through the rubber tubing into the bottle.

(NOTE. — Exhale in a natural way. Do not force all the air you can out of the lungs.)

Measure the quantity of water left in the bottle. How much water was forced out of the bottle? Estimate the number of pints of air you exhaled. Change this to cubic inches.

(NOTE. — One gallon equals 231 cubic inches.)

With a watch, count the number of times you exhale per minute. Estimate the number of cubic inches of air you exhale per minute; the number per hour. Change this to cubic feet.

Measure the dimensions of your classroom. How many cubic feet of air does it hold? How many persons are present? Determine the number of cubic feet of fresh air these persons use per hour. How often is it necessary to change this air in order to keep it fresh?

Home Problem. — Estimate approximately the number of cubic feet of air in your bedroom at home. How many persons use this bedroom? How many hours of sleep do you average per night? Estimate the cubic feet of stale air exhaled in this bedroom per night. Does the bedroom hold enough fresh air to supply your needs? How can you remedy this?

Problem 3 — How to test the air capacity of the lungs

Class Problem. — Take a gallon bottle. Glue a strip of white paper down the side, from the top to bottom. Make a scale by marking the paper with heavy black lines as follows: Fill a common drinking glass with water. Pour this into the bottle. Mark the level of the water on the paper scale. Add a second glass of water. Again mark the level of the water. Proceed in this way until the bottle is full of water. Cover the paper scale with a coating of shellac and let it dry. Each division of this scale equals approximately 15 cubic inches.

How much water can you blow out of the bottle?

Fill the bottle with water. Invert it into a large basin partly filled with water. Slip one end of a piece of rubber tubing into the mouth of the bottle. Into the other end push a piece of glass tubing, three or four inches long. In-

hale as deeply as possible. Blow through the glass tubing into the bottle. Exhale as much air as possible. From the scale read the number of cubic inches of air exhaled. Compare this with the number of cubic inches of air you exhale in a natural way.

Test the lung capacity of as many of the class as possible. (*Caution.* — Change the glass tubing for each pupil.)

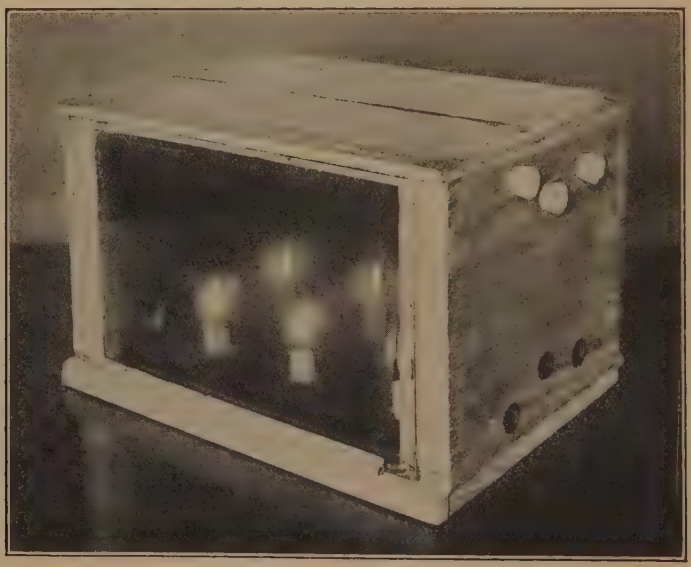
PROJECT IV

HOW TO SUPPLY OUR HOMES WITH FRESH AIR

Problems — 1. A study of ventilation.
2. How to ventilate a room.

Problem 1 — A study of ventilation

Class Problem. — Construct a box of pine boards. The size may be 12 inches long, 8 inches high, and 8 inches wide. Spread a thin layer of putty on the edges of the



This is a home-made box. You can make one like it

boards before nailing, so that all joints will be air-tight. Leave one side of the box open. Have a pane of window glass cut to fit this side of the box. Construct two grooves so that the glass front will slide up and down. Make sure that it fits tight.

In one end of the box bore 4 holes, an inch in diameter — two holes near the top and two holes near the bottom. These holes should be about 4 inches apart. In the same way bore 4 holes in the opposite end of the box. Get 8 large cork stoppers to fit these holes. Let this box represent a room, and the holes the upper and lower sashes of the windows. Cut 3 paraffin candles in halves. Set the six pieces inside the box at equal distances.

(*a*) Light the six candles. Close the 8 holes with cork stoppers. Push down the glass door. Watch the candles. *What happens?* How do you account for this?

(*b*) Open the glass door and allow fresh air to enter the box. Light the candles. Open the two upper holes in both ends of the box and close the lower ones. Push down the glass door. Watch the candles again. *What happens?* Explain.

(*c*) Fill the box with fresh air. Relight the candles. Close the upper holes and open the lower ones. Push down the glass door. *What happens?* Explain.

(*d*) Fill the box with fresh air. Relight the candles. In one end of the box open the upper holes and close the lower ones. In the opposite end of the box close the upper holes and open the lower ones. Push down the glass door. Watch the candles burn. Are the flames extinguished this time? Hold a smoking splint near the lower holes. What happens? Do the same for the upper holes. What happens? Can you explain this?

(*e*) Open the upper and lower holes in one end of the box. Close them in the opposite end. Light the candles. Push down the glass door. Do the flames go out? Hold a smoking splint near the upper holes. Now hold it near the lower holes. What happens? How do you account for this?

Problem 2 — How to ventilate a room

Class Problem. — How is your classroom supplied with fresh air? Where does it come in? Locate the opening with a smoking splint. Where does the stale air go out? Locate this opening with a smoking splint. Open a window a few inches at the top and at the bottom. Hold a smoking splint near the top. *What happens?* Hold a smoking splint near the bottom. What happens? How do you account for this? What is the best way to "air out" your classroom?

Home Problem. — How do you keep the rooms of your home supplied with fresh air? Write out a complete report on this. How do you "air out" a room? How is your bedroom supplied with fresh air at night? Do you have any fireplaces? How do these help to keep the air fresh? What system of heating do you use? What effect does this have on ventilation? Is the air in your home dry? Have you made any attempt to remedy this? What improvements do you suggest in the ventilation of your home?

FACTS EVERY ONE SHOULD KNOW ABOUT AIR

Air is real substance. " Blow up " a paper bag. Strike it a quick blow with the palm of your hand. What happens? Have you ever heard the loud *bang* of a blowout from an automobile tire? Most boys are acquainted with air rifles. These shoot a lead shot by air compressed in a small cylinder. Perhaps your mother cleans her house with air. Vacuum cleaners do better work than brooms. A revolving fan draws air in with great force, carrying with it the dirt and dust. Watch a motorman stop his car. He turns a handle, which allows air under great pressure to force the brakes against the wheels. When he starts the car again you will hear the " hiss " of this air as it escapes.

We live at the bottom of a great ocean of air more than 200 miles deep. This ocean supports the weight of flying birds, kites, and balloons. Heavy airplanes loaded with passengers or freight use it as a common highway. Air in motion is called wind. This sometimes blows off hats or raises dust in great clouds. It turns the wheels of windmills or drives sailboats over the water. At times it blows with sufficient violence to wreck buildings and uproot great trees. All this evidence proves that air is real substance.

Air is a mixture of a number of gases. The most important of these are oxygen, nitrogen, carbon dioxide, and water vapor. About one-fifth of air by volume, or 21%, is **oxygen.** This gas itself does not burn, but it is very active in helping other substances burn. Even iron and steel burn in pure oxygen. It keeps the fires going in our stoves and furnaces. In the same way it supports the combustion of a part of the digested foods in the body, to keep us warm, and to furnish the necessary power to perform our daily work.

About four-fifths of air by volume, or 78%, is **nitrogen.** This gas does not burn. Neither does it support combustion. Nitrogen helps to feed the world, for it unites with other chemical elements to make essential plant foods. Nitrogen performs another great service. It dilutes and weakens the oxygen of the air. In an atmosphere of pure oxygen everything would burn up. Even our stoves and furnaces would be consumed.

Another important gas in air is **carbon dioxide**, although the quantity present is only a small fraction of one per cent. Ten thousand gallons of air contain less than three gallons of this gas. Carbon dioxide is so heavy that it can be poured from one vessel to another, like water. It does not burn. Neither does it support combustion. In fact, less than twenty per cent of pure carbon dioxide mixed with air is sufficient to extinguish the flame of a candle. The common test for the presence of this gas is clear lime water, which is changed to a milky color.

No more wonderful change takes place in nature than the so-called *Carbon Dioxide Cycle.* This cycle begins with the giving off of carbon dioxide into the air, from the burning of fuels, decaying vegetation, fermentation, and from the breathing of plants and animals. The second stage of the cycle is performed by the green leaves of plants. These take in this carbon dioxide from the air to manufacture starch, sugar, and fuels. We burn the fuels in our stoves. Starch and sugar are eaten and burn in the body. In both cases carbon dioxide is again given off into the air. This completes the cycle. Carbon dioxide is not a poisonous gas as some people believe. We drink considerable quantities of it with every glass of tonic or soda. Even the tiny holes in the bread your mother makes are filled with this gas.

Air contains varying quantities of another invisible gas, called **water vapor**, as is shown by the formation of clouds, fog, rain, and snow. Clothes dry on the line. Wet streets and pavements are dried by the sun after a heavy rain. This water passes into the air, changing from a liquid to a gas, by a process called evaporation. Water vapor is also given off in large quantities by the leaves of green plants. The quantity of water vapor in the air affects to a marked degree our health and comfort.

In addition to these gases air contains **dust**. There are two kinds of dust, lifeless dust and living dust. Pull down a shade at a sunny window, or push it aside to make a narrow crack. Let a beam of sunlight come into the room. Examine it. You will see thousands of tiny particles of lifeless dust consisting of dirt, soot, ashes, hair, cloth fibers, etc. Clinging to these tiny particles are many invisible living organisms, such as yeasts, molds, and bacteria.

If we plant a specially prepared garden with some of this dust, these organisms will soon multiply and form great clusters, which can be seen easily with the naked eye. The germs of such diseases as colds, pneumonia, consumption, grippe, and diphtheria occur in dust. For this reason brooms and dry dust cloths are dangerous. They stir up this dust, and the air is filled with disease germs. Vacuum cleaners catch it in a large bag or tank so that it may be removed. In a similar way dust will cling to a cloth moistened with a little oil or water, and may be effectively removed. These precautions will help to make your home cleaner and more healthful to live in.

Breathing is essential to the life of both plants and animals. Deprived of air, a plant soon dies. In a similar way, if we are deprived of air, even for a few minutes, we die. Breathing is an interesting process. Take a rubber

ball with a single hole in the cover. Hold it under water and squeeze it. Bubbles of air are forced out. Now take the ball out of the water and open your hand. The elastic walls spring out. Air rushes in to fill the enlarged space. To show that it is full of air hold the ball under water again and squeeze it. In a similar way our lungs are filled with air when we inhale. Our lower ribs and breast bone are raised by the muscles. Hence the chest cavity becomes larger and air rushes into the lungs. Air is forced out again when the ribs sink back into place.

Air we breathe out contains less oxygen, more carbon dioxide, and more water vapor than air we breathe in. Compare the two following tables.

Air We Breathe In	Air We Breathe Out
Nitrogen — 77%	Nitrogen — 77%
Oxygen — 21%	Oxygen — 16%
Carbon Dioxide — $\frac{3}{100}$ of 1%	Carbon Dioxide — 4.4%
Water Vapor (average) — 1.2%	Water Vapor — 2%

When at rest we breathe about 18 times per minute. For each breath about 30 cubic inches, or one pint of air passes in and out of the lungs. Therefore, during an hour of quiet breathing we use approximately 32,400 cubic inches, or about 135 gallons of air.

A much greater quantity of air than this is used by the lungs when we exercise. We not only breathe faster, but for each breath nearly 150 cubic inches of air pass in and out of the lungs. The same fact holds true with forced breathing. Inhale, taking a long, deep breath. Now exhale, forcing out all the air you can. Nearly 150 cubic inches of air pass in and out of your lungs.

This fact is of great importance. For it shows us that during ordinary breathing we use only one-fifth of the lungs.

CHAPTER II

THE FOOD WE EAT

One of the most important things that we do is *eating*, and it is one of the pleasantest, if we eat wisely. So, for our next piece of work we will try to find out something about our food: how it is produced, what it is composed of, what different sorts of things we ought to eat, and what the use of each kind of food is.

When a man builds a new house, he chooses the bricks and lumber for its construction carefully. When he buys gasoline to make his automobile go, he selects the kinds that will furnish the most power. You, too, should select the foods you eat *carefully*, for they not only furnish the materials out of which your body is built, but also the power to make it go.

PROJECT I

WHERE OUR FOOD COMES FROM

Problems — 1. How to extract starch from a potato.
2. To find out some things about starch.
3. Do leaves contain starch?
4. Where does the starch in leaves come from?
5. What is starch made of?
6. How does the leaf get the water it needs to make starch?
7. How does the leaf get the carbon it needs to make starch?
8. How starch is changed to sugar in the plant.

Problem 1 — How to extract starch from a potato

Home Problem. — Select a large white potato. Wash it thoroughly. Scrape it with a knife or grater until it becomes a fine pulp. Put the pulp in a piece of cheesecloth or thin cotton handkerchief. Bring the corners together, forming a bag. Half fill a large bowl with clear cold water. Dip the bag into the bowl and hold it there. Knead the bag gently with the fingers for three or four minutes. Remove the bag and open it. Describe its contents. Throw this away.

Let the bowl stand for at least 15 minutes. Pour off the water, taking care that you do not lose any of the substance at the bottom of the bowl. Half fill the bowl again with clear cold water, and stir. Let it settle for at least 15 minutes. Pour off the water again. Scrape the substance which remains from the bottom of the bowl, and spread it on a sheet of paper to dry.

Watch the water as you squeeze the bag

Examine this substance. What do you think it is? Bring a sample to school to show the results of your experiment.

Problem 2 — To find out some things about starch

Class Problem. — Examine some of the starch that you have extracted from a potato. Describe it. Rub a little between your thumb and finger and examine under a good light. What do you see? What does this show about starch?

Put a small pinch of starch into a test tube. Half fill with cold water and shake. Watch it for a few minutes. What happens to the starch? Shake again. Boil the starch for a few seconds. What happens? Compare the action of hot and cold water on starch.

How to test for starch. Examine some crystals of iodine. Describe them. Make up an iodine solution as follows:

Put a few crystals of iodine into an ordinary drinking glass (the number of crystals you can easily pile on a ten-cent piece). Add a teaspoonful of potassium iodide crystals. Nearly fill the glass with cold water and stir. What happens?

Let it fall drop by drop

(NOTE. — This is called an iodine solution and is used to test starch. Pour the solution you have made into a bottle and keep it for future use.)

Put a small pinch of starch into a test tube half filled with cold water. Boil for a few seconds. Pour this starch solution into a flask. Add about half a pint of cold water and shake. With a piece of glass tubing put three or four drops of the *iodine solution* into the flask. *What happens?*

Put a few drops of iodine solution on some of your dry starch; on a little flour; on corn meal; on the cut surface of a raw potato. What is the result in each case? *How can you detect starch with iodine solution?*

(NOTE. — Iodine does not produce this color with any known substance except starch.)

Problem 3 — Do leaves contain starch?

(NOTE. — Use nasturtium leaves for this experiment. They show results more quickly and clearly than any others. Let a few members of the class, who can get nasturtium leaves, take home small bottles of denatured alcohol.)

Home Problem. — During the late afternoon of a sunny day pick two or three nasturtium leaves. Select those on

which the sun is shining. Put them into boiling water at once. Boil for four minutes. Remove and drop into a small bottle of denatured alcohol. Use a bottle with a wide mouth. Bring this to school the following morning.

Class Problem. — Remove two or three leaves from one of the bottles and put them on a white plate. Partly fill

These are nasturtiums. Do they grow in your garden?

the plate with cold water. Pour it off with care so that the leaves are spread out evenly. What is the color of the leaves? What color is the alcohol?

(NOTE. — The green coloring matter in leaves is called *Chlorophyll*.)

Pour a little iodine solution over the leaves, and after a minute pour it off. Again wash the leaves in cold water. Examine them. What color are they? What does this change of color show?

Problem 4 — Where does the starch in leaves come from?

Class Problem. — Pick a sprig of nasturtium, bearing several leaves, in the morning, before the sun strikes them. Bring this sprig to school and put it into a jar of cold water with the stem immersed. Break off one of the leaves from the sprig. Boil it for 4 minutes and drop into denatured alcohol. After 10 minutes remove the leaf and put it on a white plate. Wash with cold water. Pour a little iodine solution over the leaf. Wash again. Does it change *to a blue color?* Is starch present in this leaf? What do you think about the other leaves of the sprig — do they contain starch?

Keep the leaves in the sun all day

Set the jar with the sprig on a window sill where the sun will shine on it *all day.* Late in the afternoon break off several leaves from the sprig. Boil them for 4 minutes and drop into denatured alcohol. The next day take them out of the alcohol, wash, and test with iodine. *What change takes place in the color of these leaves?* What does this bluish color show? Does sunlight have anything to do with the presence of starch in a leaf? How do you know?

Where does the starch in these nasturtium leaves come from? Can it come from the water in the jar? Put a few drops of iodine solution into the jar. Does the water contain starch? How do you know?

Can it come from the air around the leaves? Shake up a small quantity of iodine in a flask filled with air. Can you detect any blue color? Does air contain starch?

Have the nasturtium leaves been in contact with any material besides water and air? If the leaves cannot get starch from outside of themselves, how do they get it? Where do they get the materials for manufacturing this starch? What are the only sources from which these materials can come?

Where does the starch in a potato come from? In corn? In flour?

Problem 5 — What is starch made of?

Class Problem. — Put an inch of thoroughly dry starch in the bottom of a clean dry test tube. Use a funnel in doing this, so that the upper part of the tube will remain clean and free from starch grains. Heat the starch slowly in the flame of a Bunsen burner or alcohol lamp for a few seconds. *Watch the sides of the test tube.* What do you see? What are these little drops? Where do they come from? Does this show you anything about what starch is made of?

Watch the upper part of the tube as you heat it

Now heat the starch until it burns to a crisp. Break the test tube and examine the substance that is left. What color is it? What is the black substance in coal called? In

charcoal? In burnt bread? What is the black substance in burnt starch? *What does this show you about starch?*

(NOTE. — Water is made of two gases, hydrogen and oxygen. You will learn more about these two gases in experiments which you will do later. The point to remember now is that starch is made up of three substances — carbon, hydrogen, and oxygen.)

Problem 6 — How does a leaf get the water it needs to make starch?

Class Problem. — Select a well whitened bunch of celery with good leaves. Half fill a glass with cold water and add a small quantity of red ink. With a sharp knife cut off several celery stalks near the base. Stand them with the cut ends in the glass of colored water. Set the glass on a window sill in the sun. Watch for 10 or 15 minutes. Does water go up the stems? How do you know? Does water go into the celery leaves? Does it follow any particular channels? What are the veins of leaves for?

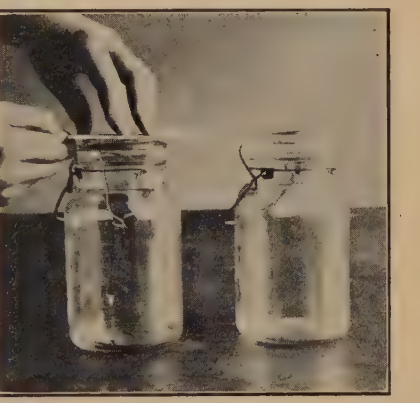
Remove a stalk of celery from the glass. With a sharp knife cut the stem across into several slices. Examine one of them. What does this show? Break open one of the celery stems lengthwise. What do you find? Pull out one of these water pipes.

How did the nasturtium leaves in Problem 4 get the water they needed to make starch? How do the leaves of corn, wheat, potato, and other plants get the water they need for this purpose?

Problem 7 — How does a leaf get the carbon it needs to make starch?

Class Problem. — Examine a small piece of charcoal. What color is it? What is the black substance in charcoal called? In coal? In coke? Can you name any other fuels that contain carbon?

Take a piece of charcoal about two inches long. With a sharp knife shave it down as thin as possible. It should not be thicker than a lead pencil. To one end attach a piece of fine wire. Take two preserve jars — quart size — with wide mouths. Ignite one end of the charcoal and blow on it until the whole end is bright red. Lower it at once into one of the jars. Cover the mouth of the jar with a piece of cardboard. *Watch this charcoal for a few minutes.* What happens? Why is the spark extinguished? Note the size of the charcoal now. Why does it become smaller? What is this charcoal composed of? What becomes of the carbon that disappears? Can it escape from the jar?



Where does the charcoal go when it burns?

Remove the piece of charcoal and re-cover the jar. Now set the two jars side by side. *Have you the same sort of gas in both jars?* To answer this question try the action of the gas in each jar on lime water thus: Pour half an inch of clear lime water into one jar. Cover with the hand and shake, so as to mix the gas and liquid. *What happens?* Treat the other jar in the same way. *What happens?* Do both jars contain the same gas? *How do you account for this?*

Lime water becomes milky in the presence of a gas called carbon dioxide, which is made up of carbon and oxygen. How did this gas get into the jar? Where did the carbon

come from? The oxygen? What happened to these two elements?

Blow through a piece of glass tubing into a jar containing clear lime water. What happen ? What does this show? What gas is formed by the b rning of coal? Of wood? Of coke? Is there any of this gas in the air? *Where do leaves get the carbon they need to make starch?* Where does the carbon in wood come from? In coal? In a potato? In a piece of bread?

Explain how the nasturtium leaves in the glass of water get the materials to make starch. Where did the hydrogen come from? The oxygen? The carbon? What happened to these elements in the leaf?

Problem 8 — How starch is changed to sugar in a plant

Class Problem. — Put a handful of ground malt into a jar. Add half a glass of warm water. Let it stand for five minutes, stirring frequently. Fold a piece of filter paper and put it into a glass funnel. Set the funnel in the mouth of a flask. Pour the contents of the jar into this filter paper, letting the clear malt solution run into the flask.

Put a generous pinch of starch into a second flask. Add a glass of water and shake. Heat over a flame until it boils. Now set six clean test tubes in a rack. Pour the same quantity of starch solution into each, filling them about one-third full. Let the solution cool until it is lukewarm.

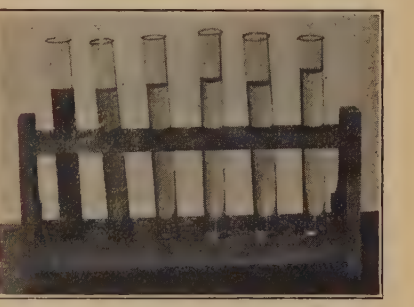
Put two or three drops of iodine into the first test tube. What happens? What does this prove? Add one and one-half teaspoonfuls of the malt solution to each of the *other* test tubes and shake thoroughly. Note the time with a watch. At the end of one minute put two or three

drops of iodine into the second test tube. At intervals of one minute put the same quantity of iodine into the third, fourth, and fifth test tubes.

Compare the colors of the solutions in the five test tubes.

How do you explain this? Do all the test tubes contain starch now? *What happened to this starch?*

Into the sixth test tube pour a few drops of Fehling's Copper Solution. Add Fehling's Alkaline Solution until the liquid changes to a deep blue. Heat until it boils. Describe the changes in color. A yellow or red color indicates the presence of sugar. What happened to the starch in the test tubes? How is starch changed to sugar in plants?



Notice the difference in the colors. Why is the first tube darker than the last?

(NOTE. — The substance in malt that changes starch into sugar is called diastase. It exists in barley and other grains and also in the leaves of plants. It may be purchased at a drug store and used in place of malt solution.)

From the experiments which you have had so far, you have learned that starch is made in the green leaves of plants under the influence of sunlight. You have also learned something about the materials of which it is made and how the plant gets those materials.

Plants use the starch they make as building material from which to construct more leaves, stems, roots, etc. In many cases they store away a part of the starch in fruits, stems, or roots, for use the succeeding year.

PROJECT II

THE KINDS OF FOOD WE EAT

Home Problem. — We have learned that we get starch from potatoes. Where do we get the following foods?

Mutton	Olive Oil	Oatmeal	Prunes
Veal	Cheese	Buckwheat	Macaroni
Lard	Graham Flour	Raisins	Table Salt

List the different kinds of food you eat according to the following plan.

Animal Foods	Plant Foods	Mineral Foods

Show how animals depend upon plants for food. Where do plants get this food? How do we depend upon the soil for our food? How can an apple come from the soil? An egg? A slice of bread? A piece of beef?

Copy the following table. Classify the foods you eat, writing the names of each in the proper column.

Meat	Fish	Dairy Products	Cereals	Vege-tables	Fruits and Nuts	Sweets

In which column do you put milk? Cheese? Bread? Beans? Honey? Apples? Asparagus? Rice? Raisins? Oatmeal? *Why do you eat so many kinds of food?*

PROJECT III

WHAT FOODS ARE COMPOSED OF

Problems — 1. To find what milk is composed of.
2. How to test foods.
3. Do foods contain water?
4. The composition of food.

Problem 1 — To find what milk is composed of

Class Problem. — (*a*) Put a pint of fresh milk into a cylindrical jar, and let it stand overnight. The next day examine the top of the milk. What do you find? Measure with a ruler the amount of cream in the milk. Estimate the percentage of cream approximately.

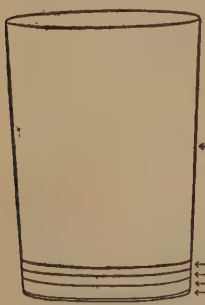
What is the percentage of cream in this jar?

Dip out the cream with a spoon. Put it into a small flask. Stopper and shake the flask for about ten minutes. What happens? Remove the butter and make it into a single lump. *Does milk contain fat?*

(*b*) Pour about two inches of milk into a test tube. Add two or three drops of iodine solution. Does the color of the milk change to blue? *Does milk contain starch?*

(*c*) Put a small quantity of the milk into a test tube and heat. Bring the mouth of a flask or beaker down over the mouth of the test tube. Hold it there for a few seconds. Examine the inside. What do you find? *Does milk contain water?*

(*d*) Pour the rest of the skim milk into a flask. Add about two teaspoons of concentrated hydrochloric acid. Warm the milk. What happens? Lay a piece of cheesecloth over the top of a beaker and pour the contents of the flask into it. Bring together the four corners of the cloth, and squeeze the curds as dry as possible. Examine the curds. What is cheese? How is it made? Notice the liquid in the beaker. This is called whey. Put about an inch of the curds into a test tube. Add a few drops of nitric acid and heat until it starts to boil. Let it cool and add ammonia, a few drops at a time. What changes take place in the color of the milk? If a substance is colored yellow by nitric acid, changing to orange when ammonia is added, it contains **protein**. *Does milk contain protein?* The word protein may be new to you but the substance protein is not. It occurs in many of your foods and is essential to your well-being.



A glass of milk

(*e*) Put two or three tablespoons of the whey into the cover of a coffee can. Heat over a hot flame. Let the whey dry and burn to a crisp. What is the black substance? Burn this black substance for several minutes until it disappears. Let the cover cool. Examine the contents. Describe it. Rub a little on your finger. What is it? What is left after wood burns? *Does milk contain ash?*

(*f*) Put about an inch of the whey into a test tube. Add a few drops of Fehling's Copper Solution. Next add a small quantity of Fehling's Alkaline Solution until the liquid changes to a deep blue. Heat until it starts to boil. Does the color change to yellow or red? (See Problem 8, page 33.) *Does milk contain sugar?*

The sugar in milk is called milk sugar, and may be purchased at drug stores.

Does milk contain fat? Sugar? Water? Starch? Protein? Ash?

Problem 2 — How to test foods

Class Problem. — Test each of the following foods for starch, sugar, and protein.

1. White meat of chicken or fish, chopped fine.
2. The white of an egg.
3. White flour.
4. A small onion chopped fine.
5. A few white beans soaked overnight and crushed to a pulp.
6. Apple pulp (peel apple and scrape with a knife).
7. Walnuts crushed to a pulp.
8. Sirup or honey.
9. Olive oil.

Test each food as follows: Take three test tubes. Put an inch of the food into each. Add a little water and shake. (Omit water with the sirup and olive oil.) Test the food in the first test tube for starch, in the second for sugar, and in the third for protein.

Home Problem. — Crush the meats of two or three walnuts to a pulp. Make a small pile on a piece of brown paper. Heat in the oven for a few minutes. *Examine the paper.* What does this show about walnuts? Compare with a drop of olive oil or melted butter on paper.

For fats in the other foods tested consult Problem 4, page 40.

Copy the following table. Write "Yes" or "No" in the proper columns to show the results of your tests.

Food Tested	Starch	Sugar	Protein	Fat
Meat				
Egg White				
White Flour				
Onion				
Beans				
Apple				
Walnuts				
Sirup				
Olive Oil				

Which foods contain starch, sugar, protein, and fat? Which contain only protein? Only starch? Only sugar? Only fat? Can you name any other foods that are rich in protein? Rich in starch? Rich in sugar? Rich in fat?

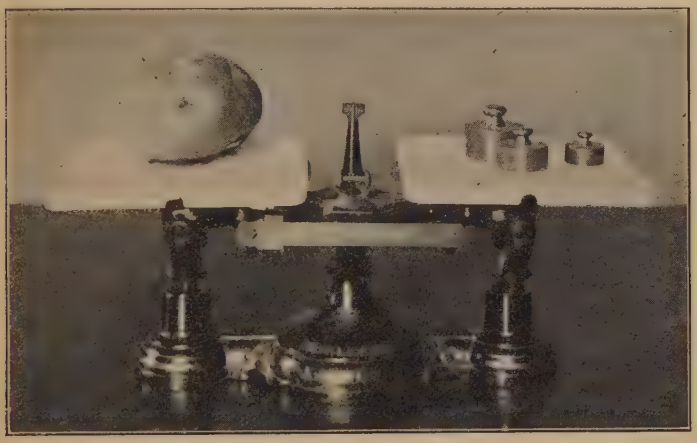
Problem 3 — Do foods contain water?

Class Problem.— Take a medium-sized potato. Weigh it carefully. With a grater, scrape the potato to a fine pulp. Spread the pulp in a large shallow plate, making a thin even layer. Some of the pulp will stick to the grater. Get it off carefully and put it in the plate. Set the plate on a radiator or back of a stove for two days. *What happens?* Scrape what is left from the plate and weigh again. Estimate as follows:

Weight of potato = ?
Weight of dry pulp = ?
Loss in weight = ?
Per cent of water = ?

How many pounds of water are there in a bushel of po-

tatoes? What is the cost of potatoes per bushel? How much do you pay for water?



Use the best scales that you can get. These will weigh a small fraction of an ounce

The amount of water in some of our common foods is as follows:

$\frac{9}{10}$ *water*	$\frac{5}{8}$ *water*	$\frac{3}{4}$ *water*	$\frac{1}{2}$ *water*
Milk	Fresh Fish	Eggs	Beef
Onions	Parsnips	Bananas	Lamb
Celery	Apples	Green Corn	Pork
Lettuce	Pears		
Strawberries	Oatmeal (cooked)		

Problem 4 — The composition of food

Home Problem. — Consult the following table and diagrams showing the composition of foods. Pick out the five foods containing the highest percentage of protein. The five foods containing the highest percentage of carbohydrate. Of fat. Of water. Of ash.

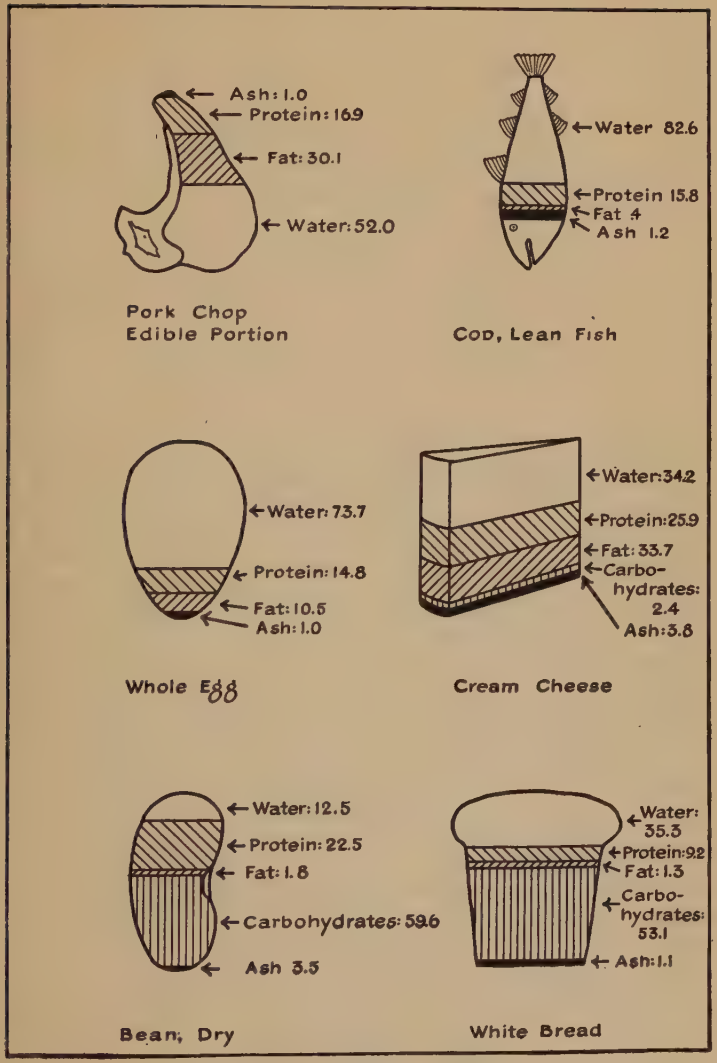
(NOTE. — Starch and sugars are called carbohydrates.)

Arrange in a table as follows:

Rich in Protein	Rich in Carbohydrates	Rich in Fat	Rich in Water	Rich in Ash

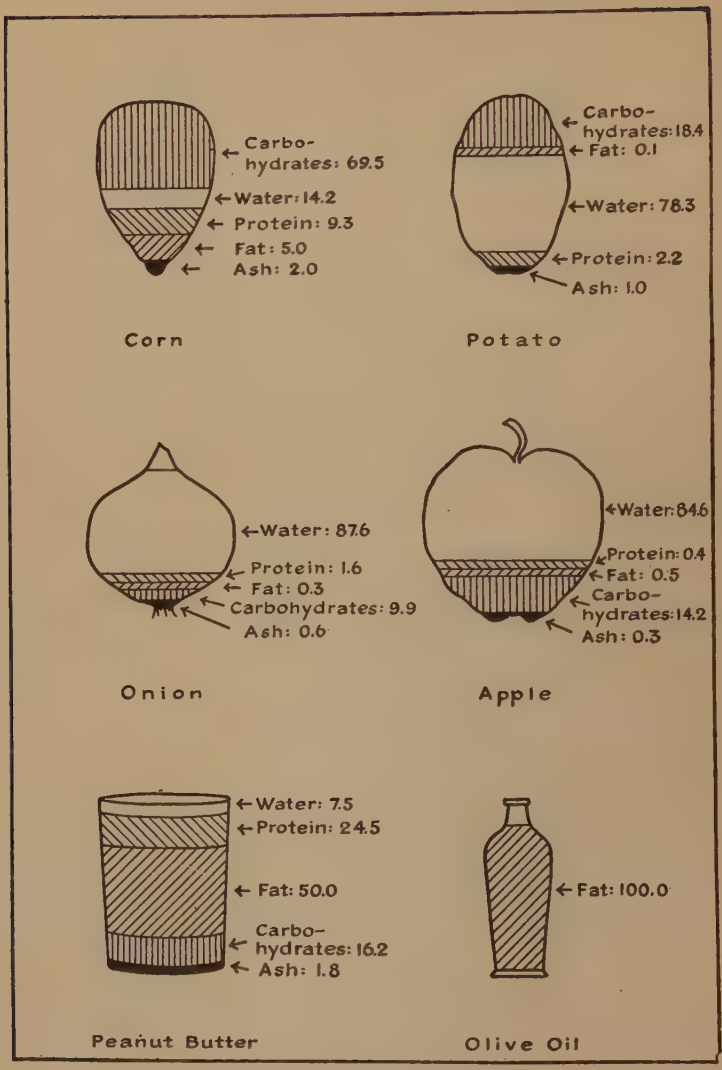
Table Showing the Composition of Common Foods

Food	Per Cent of Protein	Per Cent of Carbo-hydrates	Per Cent of Fat	Per Cent of Water	Per Cent of Ash
Beefsteak	18.6	None	18.5	61.9	1.0
Dried Beef	30.0	None	6.6	54.3	9.1
Oysters	6.2	3.7	1.2	86.9	2.0
Mackerel	18.3	3.7	7.1	73.4	1.2
Rice	8.0	77.0	2.0	12.0	1.0
Oatmeal (cooked)	2.8	11.5	0.5	84.5	0.7
Corn Bread	7.9	46.3	4.7	38.9	2.2
Parsnip	1.6	13.5	0.5	83.0	1.4
Celery	1.1	3.4	None	94.5	1.0
Banana	1.3	22.0	0.6	75.3	0.8
Bacon	9.4	None	67.4	18.8	4.4
Butter	1.0	None	85.0	11.0	3.0
Lard	None	None	100.0	None	None
Sugar	None	100.0	None	None	None



Percentage composition of foods

(After Langworthy)



Percentage composition of foods

(After Langworthy)

PROJECT IV

WHY WE EAT FOOD

Problems — 1. The muscle-building foods.
2. Does food burn?
3. Do foods burn in the body?

Problem 1 — The muscle-building foods

The lean meat of animals is composed of muscle. We should expect, therefore, that lean meat must contain the

These foods contain protein. They are muscle-building foods

materials needed to build muscle in our own bodies. This is true. These building materials are called proteins. Protein is the *only* nutrient in foods that can furnish the materials needed for the growth of muscle. Starch, sugars, and fats make fat but no muscle.

Home Problem. — Pick out the muscle-building foods from the preceding table and diagrams. Arrange as follows:

Over 15% Protein	5 to 15% Protein	Under 5% Protein

(Note. — Although milk contains less than 5% protein, it is a valuable food for muscle building.)

Which are the better foods for muscle building? Explain.

Eggs or Butter?	Apples or Nuts?
Beans or Potatoes?	Cheese or Honey?

You need about two ounces of protein every day. How many ounces of protein are there in a pound of beefsteak? In a pound of cheese? In a pound of apples? In a pound of honey?

Weigh a slice of bread. Estimate the number of slices it would be necessary to eat for two ounces of protein. Weigh a potato and estimate in the same way.

Write a list of the muscle-building foods you ate to-day.

Problem 2 — Does food burn?

Home Problem. — (*a*) *Does protein burn?* Put a small piece of meat in an old iron tablespoon. Hold the spoon over a hot flame for several minutes. What causes the hissing sound? Describe the odor. This odor is produced when any protein burns. With a match ignite the piece of meat. Watch it burn. What is left in the spoon? What color is it? What is the black substance in meat called?

(*b*) *Does starch burn?* Put a small quantity of starch into the spoon, and heat it over a hot flame. Ignite the starch with a burning match. Watch the starch burn. What is left in the spoon? What is the black substance in a piece of toasted bread?

See the starch burn. Is it a good fuel?

(*c*) *Does sugar burn?* Burn a small quantity of sugar in the spoon. Describe how it burns. What is left in the spoon?

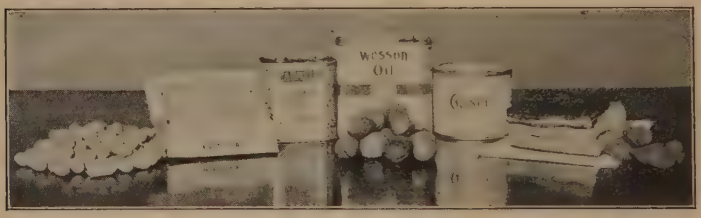
(*d*) *Does fat burn?* Put a small piece of lard or butter into the spoon and heat. Ignite the fat. Watch it burn. Which do you consider the best fuel, protein, starch, sugar, or fat? What is left in the spoon? What is the black substance called? Can you show that there is carbon in a potato? In an apple? In a piece of fish?

These are good fuel foods. They are called carbohydrates

Problem 3 — Do foods burn in the body?

Class Problem. — What is the temperature of your body? Of the room? What is the outside temperature? What keeps the body warm? How do you warm your kitchen at home? What keeps your body at blood heat during the cold winter months?

Pour an inch of clear lime water into a flask. Blow through a piece of glass tubing into the lime water for several seconds. *What happens?* What gas causes this?



Fats are the best fuel foods

(See Problem 3, page 9.) Where does it come from? What is it composed of? How is it formed in the body? Where does the carbon come from? The oxygen? What gas is given off when a piece of charcoal burns? How is this gas formed?

What kind of fuel is used in a steam engine? What kind of fuel is used in the body? What does a fireman do when he wants his engine to run faster? Why does he use more coal? Why does he open his drafts? Why do the boilers become hotter? Why do you eat more when you play or work hard? Why do you get out of breath when you run? Why does violent exercise make you perspire? Explain how a hearty breakfast helps you to do a hard day's work.

If you have followed the work with care up to this point, and have drawn the right conclusions from the experiments you have done, you have learned how necessary it is for

you to eat foods of different kinds. Foods that make muscle, you must have, of course. But just as important are the foods that keep you warm and furnish the power for doing the day's work. Besides these, you must eat some things for the mineral matter they contain. Cereals, vegetables, and fruits are rich in iron, sulphur, phosphorus, lime, sodium, and other minerals, which are needed for making bone, blood, and tissue. It is also very essential

Eat plenty of vegetables and fruit. They are rich in mineral matter and in vitamines

that your food should contain certain minute crystalline substances, called **vitamines**. These are found mostly in raw or uncooked foods, such as milk, yeast, fresh fruits, and vegetables. These vitamines are essential to life, as they help to maintain the health and vigor of the body.

In addition to this your food must not be too concentrated. You need to eat coarse bread, cabbage, celery, spinach, apples, pears, etc. These bulky or coarse foods aid in digestion and help to keep you in good trim.

Now it will be a good plan to make a study of what you actually do eat, to see if you are neglecting any of the essential foods.

PROJECT V

A DAY'S RATION AND WHAT IT MEANS

Problem 1 — Is my day's ration well balanced?

Home Problem. — Keep a record of the foods you eat for one day. Arrange them in a table as shown below. Write the names of the foods in the first column. In the other columns write "Yes" or "No" to show any benefits you may derive from them. Each column should be well represented in order that you may have a well-balanced ration.

Food Served	Protein	Fat	Carbohydrates (Starch and Sugar)	Mineral Matter	Vitamines
	Helps to make muscle for growth and repair.	Burns, giving heat and power.	Burns, giving heat and power. Also makes fat.	Helps to make bone, teeth, blood, etc.	Helps to maintain the health and vigor of the body.
1 glass of milk	Yes	Yes	Yes	Yes	Yes
1 baked potato	No	No	Yes	Yes	No
1 piece of apple pie	No	Yes	Yes	No	No

Examine the table. Are all five columns well represented in your ration? What kinds of foods have you neglected? What kinds have you eaten to excess? What improvements do you suggest?

PROJECT VI

HOW FOODS ARE DIGESTED

Problems — 1. The digestion of starch.
2. How digested food passes into the blood.
3. The organs of digestion.

Digestion is a wonderful process. Different juices in your mouth, stomach, and intestines can change the solid foods you eat to liquids. Solid foods cannot pass through the walls of the intestines into the blood. They must first be changed to liquids. In this condition they pass into your blood and furnish fuel and building materials. The following experiment will show you some of the interesting things about digestion and how it goes on.

Problem 1 — The digestion of starch

Class Problem. — Put a generous pinch of starch into a flask. Add a drinking glass full of water. Shake. Heat until the water boils for a few seconds. Set five clean test tubes in a rack. Pour an inch of the starch solution into each. Let them cool until lukewarm. Put two or three drops of iodine into the first test tube. *What happens?* What does this prove?

Put a generous mouthful of saliva into each of the other four test tubes. Shake thoroughly. At intervals of two minutes put two or three drops of iodine into the second, third, and fourth test tubes. Compare the colors. Explain. Does the solution in the fourth test tube change to blue? What does this prove?

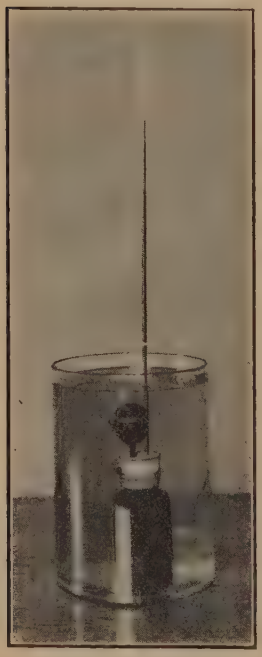
What becomes of the starch? Test the solution in the fifth test tube with Fehling's Solution. What is the result? What becomes of the starch?

Explain the action of the saliva on starchy foods, such as potatoes, bread, macaroni, and rice. Should we chew our food thoroughly before swallowing it? Why?

The digestion of starchy foods which is begun by the action of saliva in the mouth is completed by other liquids in the small intestine. The digestion of protein is begun in the stomach by the gastric juice and this, too, is completed in the small intestine.

Problem 2 — How digested food passes into the blood

Most of the digested food passes through the walls of the small intestine into the blood. *How does it do this?* The walls of the small intestine do not contain any visible openings for food to pass through.



Watch the liquid rise. It works like magic

Class Problem. — Remove the membrane or inside lining from an egg shell. Let several members of the class volunteer to try it at home. Break an uncooked egg in halves as neatly as possible. Remove the yolk and egg white. Now break away a little of the shell around the edge to start the membrane. Using the thumb and forefinger pull it away from the shell very gently, bending it as far back on itself as possible. With care a large piece can be taken out without tearing it. Hold the egg membrane to the light and try to look through it. Do you see any openings?

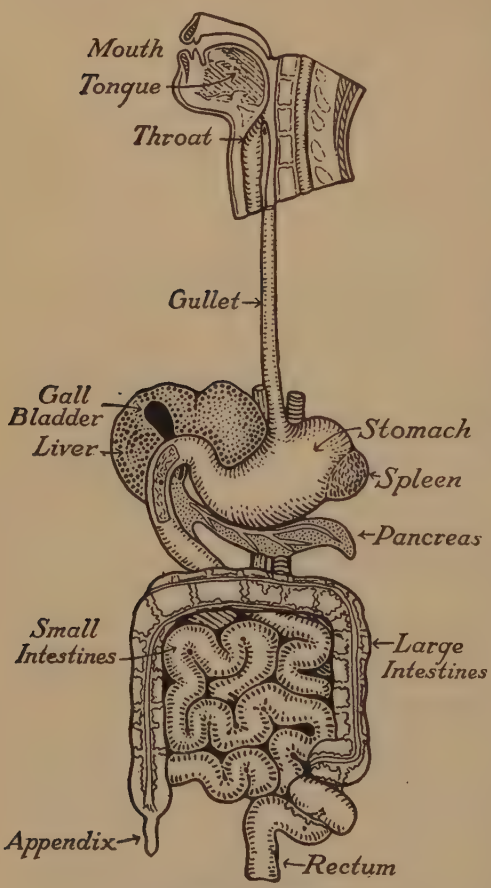
Take a small bottle with a mouth about an inch in diameter and a two-hole rubber stopper to fit it. Break

off the stem of a thistle tube so that it is about an inch long. Push this through one hole in the stopper. Stir two or three spoonfuls of black ink into a small can of Karo Corn Sirup. Pour this into the bottle until it runs over. Now fill the thistle tube, bowl and stem with sirup, so as to exclude all air. Push the stopper quickly and firmly into the mouth of the bottle. Let an assistant press a finger over the open hole in the rubber stopper, and keep it there. Pour a little more sirup into the thistle tube so that it runs over, and then lay a large piece of egg membrane over it, *taking care to exclude air bubbles*. Tie the egg membrane around the mouth of the thistle tube tightly, with a dozen or more windings of string. Remove the finger from the second hole in the stopper and push through it one end of a piece of capillary glass tubing, two or three feet long. Fill a large glass jar with clear cold water. Set the bottle into it so that the thistle tube and egg membrane are under water. Tie a piece of string around the glass tubing to mark the level of the sirup.

Watch it for ten or fifteen minutes. What happens? Does the liquid rise in the glass tubing? Is the bottle still full? Do the bottle and glass tubing contain more liquid than before? Where does this additional liquid come from? Does water pass through the egg membrane? Which liquid is thicker, the sirup or the water? Which then contains *the stronger solution*, the glass bottle or the jar? In which direction then do liquids move when they pass through a membrane, toward the stronger or toward the weaker solution? This movement of liquids through a membrane is called **osmosis.** Explain how digested food passes through the walls of the intestines into the blood. Why must the food be in a liquid form? What then is the purpose of digestion?

Problem 3 — The organs of digestion

Home Problem. — (*a*) Copy the following diagram and label the principal organs of digestion.



The organs of digestion

(*b*) Trace the course of the food from the mouth to the rectum.

(*c*) Explain how digestion takes place in the mouth. Why do we chew food? What does saliva do?

(*d*) Digestion in the stomach. Here the food is thoroughly churned and mixed with gastric juice, which contains hydrochloric acid and pepsin. Gastric juice begins the digestion of proteins.

(*e*) Digestion in the small intestine. The juices from the gall bladder and pancreas are poured into the small intestine, and complete the digestion of starches, proteins, and fats.

FACTS EVERY ONE SHOULD KNOW ABOUT FOOD

Plants are the food makers of the world. Every green leaf is a factory with thousands of little rooms, called cells. These rooms are furnished with microscopic machines, called chlorophyll bodies. Power is supplied by sunlight. On the surface of every leaf are thousands of tiny pores, called **stomata.** Through these, carbon dioxide, composed of carbon and oxygen, passes from the air into the cells of the leaf. Water, composed of hydrogen and oxygen, is absorbed from the soil. From these two raw materials, starch, composed of carbon, hydrogen, and oxygen, is manufactured by the leaf. Every sunny day in summer, green leaves are busy making starch and storing it away to help feed the world. The fruits and vegetables we eat, the grains of cereals which are ground into flour and meal, are for the most part the storehouses of the plants.

Another substance made in plants is **sugar.** Some of this comes from starch, which is changed into sugar by diastase. Certain plants, however, do not make any starch, but produce sugar and other food substances directly. From such plants as sugar cane, beet, and maple, thousands of tons of sugar are extracted yearly for our use.

Plants also manufacture proteins. Besides carbon, hydrogen, and oxygen, proteins always contain nitrogen, and often phosphorus and sulphur. Fertile soils contain these chemical elements; but it is usually necessary to add them in the form of manures or chemical fertilizers to fields from which crops have been harvested. These are dissolved by soil water and absorbed by the plant roots. Vegetable proteins manufactured in this way by plants are eaten by animals and transformed into the animal proteins of milk, cheese, and meats. Animals depend upon

growing plants for their food. Plants in turn depend upon mineral matter obtained from the soil. Hence, the maintenance of soil fertility is essential to supply man with the enormous quantities of foodstuffs he needs.

You must eat a variety of foods. Foods contain proteins, carbohydrates, fats, mineral matter, vitamines, and water. Proteins make muscle. They alone can furnish the necessary material to build and repair tissue. To grow large and strong, you must eat such foods as meats, fish, milk, cheese, beans, and peas. Carbohydrates (starch and sugars) are the "fuel" foods. They burn in the body, giving heat and power. They also make fat. Starch is found mostly in such foods as oatmeal, bread, rice, macaroni, and potatoes. Sugars are found in honey, molasses, sirups, sugar, and fruits. Fats are essential nutrients. In the first place, they are the best fuels, giving two and one-half times as much heat and power as carbohydrates. They act as body regulators, especially helping digestion. They are also changed to fatty tissue in the body. Fats are obtained from meats, butter, pork, lard, oils, and nuts.

Mineral matter is needed to furnish the necessary materials for making bone, blood, and tissue. Cereals, fruits, and vegetables are especially rich in mineral matter. Have you ever seen a soft-shelled egg? Egg shells contain lime. When hens are deprived of foods rich in lime, such as broken oyster shells, they frequently lay eggs with a soft shell. Bones contain considerable quantities of lime and phosphorus. For this reason the growing bones of boys and girls need plenty of these minerals to use as building material. In the manufacture of some cereal foods, the outer coating of the kernel is removed to improve the appearance. Much of the valuable matter is thus lost. This is especially true of polished rice and white

flour. Graham flour, made from whole wheat, contains three to four times as much mineral matter as white flour.

Some foods contain minute crystalline substances called vitamines. These are essential to help maintain the bodily health and vigor. Animals deprived of these may become ill and die. Scurvy is a common disease on shipboard and in army camps. This is caused by eating foods deficient in vitamines, such as salt meats and canned goods. Raw meat, milk, cabbage, and carrots are especially rich in vitamines. They are also found in butter, eggs, cereals, fresh fruits, and raw vegetables.

Eat wisely if you wish to keep well. We feed corn to hogs and cattle to make them fat; hens are fed with meat scraps to make them lay; cows are fed gluten and cotton-seed meal to produce milk. We feed animals scientifically. Man, however, too often relies on his own appetite for a proper selection of food. He may develop an unnatural craving for alcohol, stuff himself with highly seasoned desserts, or satisfy his appetite with excessive quantities of proteins. He is paving the way for diseases such as kidney trouble, diabetes, gout, and dyspepsia. Sooner or later, he suffers the consequences of his improper diet in impaired efficiency, diseases, and a shortened life.

To avoid errors in eating the appetite should be guided by intelligence. A well-balanced diet should include proteins, carbohydrates, fats, mineral salts, and vitamines. Drink plenty of fresh milk. Eat fresh fruits or green vegetables every day. Avoid foods that are too highly refined. Coarse foods, such as whole wheat, rye, oatmeal, cabbage, and greens are needed by the body. An excellent breakfast consists of an orange, a dish of oatmeal and cream, a slice of toast and butter, a soft-boiled egg, and a glass of milk. It will not only help to keep the body in fighting

trim, but also furnish the energy needed to accomplish successfully the morning's work. Many failures in school and business are caused by deficient breakfasts. Like the automobile or steam engine the body should be supplied with a sufficient amount of the proper fuel to get the best results.

Right habits of eating should accompany the right selection of foods. Eat slowly. Chew your food well and mix it thoroughly with saliva before swallowing. Stop when you have eaten enough. Don't stuff. This only puts an extra burden on the organs of digestion. Eat regularly. Lunches between meals are harmful, for the stomach should be given periods of rest.

Digestion. — Most of the digested food passes through the walls of the small intestine into the blood by a process called osmosis. To do this, food must be changed from a solid to a liquid. This is called digestion. It begins in the mouth, where some of the starch is changed to sugar by the saliva. The food next passes into the stomach, where the gastric juice acts upon it. Here hydrochloric acid dissolves some of the mineral salts, while pepsin changes some of the solid proteins to a liquid. In the small intestine several digestive ferments act upon the food. The pancreatic juice changes starch to sugar, proteins to soluble **peptones**, and helps to break up the fats. Bile, from the gall bladder, also acts on fats changing them to a soluble form. Digested food is carried by the blood to all parts of the body. Some of it is built into tissue. The rest unites with oxygen from the lungs, and burns, giving heat and power. At the same time, waste materials are constantly being thrown off from the body through the skin, lungs, kidneys, and the large intestines.

A common ailment of young people is constipation. The

large intestine becomes clogged with waste materials; and poisonous substances are absorbed by the blood, causing nausea, headaches, and frequently much suffering. Constipation is brought on in three ways. First, by the failure to form the habit of emptying the large intestine each day. Second, by lack of exercise, and third, by eating foods too highly refined. Drugs and pills should be used only as an extreme measure. The proper remedy lies in correcting these three bad habits. Empty the large intestine every day. Exercise regularly. Eat some coarse foods, such as rye bread, bran muffins, apples, and cabbage.

Buy right and save money. A great saving may be made in every household by buying foods in season, when they are cheapest, and storing them away for future use. Many fruits and vegetables may be dried, or canned. The Department of Agriculture at Washington will send you pamphlets giving reliable directions for drying and canning foods. Eggs keep well in water glass. You can purchase this, with directions, from any grocer. Every home should practice economy in these ways, as it means a great saving in the cost of living.

Buy the cheaper cuts of meats. These have just as much food value as sirloin roasts, porterhouse steak, or chops. Soups, stews, pot roasts, pies, and many other nutritious dishes may be prepared from them at a great reduction in cost. Hamburg steak at 20 cents per pound is equivalent in food value to sirloin at 50 cents per pound. Oatmeal at 6 cents per pound is a far better food than oysters at 50 cents per pound.

Patronize clean stores and markets. Keep a set of reliable scales at home. Weigh all foods you buy. Too much emphasis cannot be laid on this, as it protects you against careless and dishonest dealers.

When you purchase meats insist on the trimmings. You pay for these, and they may be used for making stews or soup. In cities unless one can afford "certified milk" it is safest to buy pasteurized milk. This has been heated for about 20 minutes at temperatures from 140° F. to 160° F., and most of the harmful bacteria are destroyed. Unclean or contaminated milk is the cause of many serious diseases. "Ptomaine poisoning" may be caused by spoiled canned goods. When you open a can examine it carefully. Does gas escape? Does it have a peculiar taste? If so, reject it. Some meats are infested with little animals. These enter the body and cause serious diseases. Tapeworms are sometimes found in beef. Trichina, another parasite, lives in pork. To protect yourself against these, cook all meats thoroughly.

Be on the watch for adulteration. In spite of pure food laws, substitution, adulteration, and the addition of harmful preservatives to foods are still practiced. Boric acid is used to keep meats fresh, and formalin to prevent milk from souring. Coal tar dyes are put into jams and cheap candies to color them. The green color of canned peas may be due to the addition of poisonous copper salts. Cheaper substitutes are sometimes mixed with foods; such as cereals in Frankfurts, cottonseed oil in olive oil, glucose in honey and chicory in coffee.

CHAPTER III

THE WATER WE DRINK

THERE is no greater magician in nature than water. Whether we see it as pure white flakes of snow crystals, as fairylike patterns of frost pictures, as cold hard sheets of glistening ice, or as clear sparkling drops of falling rain — whether it disappears from sight to become visible again as soft fleecy clouds — it is only one of the many magical changes that water is continually passing through. We are constantly made aware of its presence, when we drink it, cook with it, wash our clothes, take a bath, warm our homes, or when we listen to hissing steam, pattering raindrops, bubbling brooks, splashing waves, or the thunder of great falls. Water seems to be everywhere, over us, under us, about us, and in us; we ourselves are considerably over half water.

In spite of these facts we seldom realize how much we owe to water for our health and comfort, or even for life itself.

The following chapter contains many interesting experiments to show you some of the remarkable facts about water and what it contributes to our welfare.

PROJECT I

WHAT WATER IS COMPOSED OF

Problems — 1. A study of hydrogen.
2. How to separate water into its parts.

Problem 1 — A study of hydrogen

Class Problem. — (*a*) As a sort of introduction to hydrogen, and to see how it acts, make a little at first in this way. Into a test tube put enough granulated zinc to fill about an inch from the bottom. Cover this with water and add about one-third as much strong hydrochloric acid as you have water. What happens? What is given off? What is the color of the gas? Can you see it coming out of the test tube?

After a minute or two hold a lighted splinter at the mouth of the tube. Does the gas burn? Now we are ready for one or two interesting experiments; but to do them we shall need a larger quantity of hydrogen. To get it proceed as follows:

(*b*) Instead of the test tube use a half-pint bottle, that is, one that will hold a drinking glass full of water. The bottle must have a wide mouth and you must have a two-hole rubber stopper to fit it. Into the bottle put a small handful of granulated zinc and cover it with water. Now put in the stopper and through one hole put a thistle tube so that the lower end will be under water. Through the other hole in the stopper put one end of a short piece of glass tubing that has been bent to a right angle. On the other end of this tubing slip a piece of rubber tubing, which is two feet, at least, in length. (If it is too short you will be apt to upset the bottle.) Slip the end of the rubber tubing over the end of a six-inch piece of glass tubing. *Make*

sure that all joints are tight. Have ready a clean, dry quart milk bottle to catch the gas in, and a thin splinter of wood six or eight inches long. (The milk bottle has a mouth of the right width and being heavy it does not overheat during the experiment.) Have no flame near your apparatus; but a lighted Bunsen burner three or four feet away will be convenient to light the splinter later.

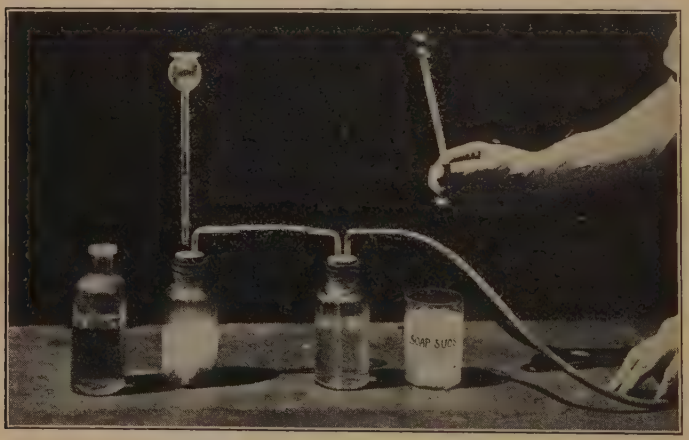
Keep the bottle inverted. Push the glass tubing way up

Now if you are all ready, pour enough strong hydrochloric acid into the thistle tube to start vigorous action in the bottle. Let the gas escape for at least two minutes to be sure that all air is out of the apparatus. Now hold the milk bottle *upside down* and stick the end of the delivery tube inside, clear to the top. Hold it there for at least two minutes.

The bottle is now full of hydrogen. Lay down the tube, put your hand over the mouth of the bottle, and walk over to the lighted burner. Now put the splinter, which a pupil has lighted for you, halfway into the bottle. Does the gas burn? Where does it burn? Does the flame give much light? Does the stick burn in the bottle or does it "go out"? Draw the stick down slowly and see if you can relight it at the mouth of the bottle. See how

many times you can do this. Look at the sides of the bottle. What can you see? When hydrogen "burns" it combines with the oxygen of the air just as carbon did in a previous experiment. The result of this combination is the drops on the side of the bottle.

(*c*) *To show something about the weight of hydrogen.* Half fill a glass with water and add a piece of soap. The water should be soft and you should use castile soap to get good



Don't try to blow the bubbles too large

results. If your water is "hard" use rain water. Cover the glass with one hand and shake vigorously till you have good suds. Skim off the foam, and you are ready to blow bubbles. Have your generator acting vigorously. Add more zinc and acid if necessary. Dip the end of the delivery tube into the suds and quickly turn it so that it points directly up. When the bubble is an inch or more in diameter a slight, quick, downward pull on the tube will release it. Can you blow bubbles with hydrogen? If you do not succeed, shake up your suds so as to make it stronger and try again. Where does the bubble go, up or down? Why?

Do bubbles blown by the breath go up or down? Why? How does hydrogen compare with air in weight? You will find it good fun to try to get bubbles of different sizes.

Problem 2 — How to separate water into its parts

Class Problem. — To find what water is composed of, we can take it apart with electricity. Set up the Hoffman's Apparatus as shown in the illustration.

Look at the gas in each cylinder. Where does it come from?

First push the stoppers into the ends of the glass cylinders. Clamp the apparatus to a ring stand, taking care not to break it. Open stop cocks *B* and *C*. To half a pint of cold water add three tablespoonfuls of strong sulphuric acid. Do not pour sulphuric acid directly into the spoon, but put three tablespoonfuls of water into a test tube. Now pour out the water and fill the test tube with sulphuric acid to the same mark. Pour this mixture slowly into reservoir *A*, filling the glass cylinders *D* and *E*. Take care to drive out all air bubbles. Close the stop cocks. Now fill the middle glass tube with the mixture up to the bottom of the reservoir.

Use extreme caution in handling sulphuric acid. It burns the skin and destroys clothing. Always add the acid to water very slowly, never pour water into the acid. Sulphuric acid is added to hasten the action of electricity in breaking up the water. None of it is used up during the experiment.

Connect six *new* dry cells, from carbon to zinc, as shown. Now fasten the ends of the copper wires from the dry cells to the apparatus. What happens? What are the little bubbles? What do they contain? Where do these bubbles come from? How are they formed? Where do the bubbles go? What comes out of them when they burst? Watch the water in each cylinder. What happens? What pushes it down? Does each cylinder contain the same quantity of gas? How do you account for this? Call one gas, the gas of greater quantity; the other, the gas of lesser quantity.

Using a foot rule measure the quantity of gas in each cylinder. Estimate as follows:

Gas of greater quantity = inches.
Gas of lesser quantity = inches.

How many gases does water seem to be composed of? What is the relative quantity of these two gases?

Make a careful study of these two gases as follows: Take a piece of glass tubing four inches long. Slip a piece of rubber tubing three inches long over one end. Push the other end of the rubber tubing over the tip of one of the cylinders. Invert a clean dry test tube. Bring the mouth of this test tube down over the end of the glass tubing, letting it reach nearly to the bottom. Open the stop cock slowly. Let just enough gas escape from the cylinder to fill the test tube.

Examine the gas of greater quantity. Fill a clean dry test tube with the gas of greater quantity. Be sure to hold it upside down until the experiment is finished. Why? What color is this gas? Hold a burning splint near the mouth of the test tube. What happens? What color is the flame? Examine the inside of the test tube. What do you see? Where do these drops of water come from? Have you already had a gas which acts like this? What do you think this gas is?

Open the stop cock slowly. The rise of water shows how much gas escapes

Examine the gas of lesser quantity. Fill a clean dry test tube with the gas of lesser quantity. Keep the thumb pressed tightly over the mouth of the test tube. What color is this gas? Light a slender wooden splint. Blow out the flame. Thrust the spark into the test tube. What happens? Repeat several times. Does this gas burn? *What does this gas do?* Have you already had a gas which acts like this? What do you think this gas is?

How many gases is water composed of? What is the relative quantity of each gas?

PROJECT II

A STUDY OF ICE

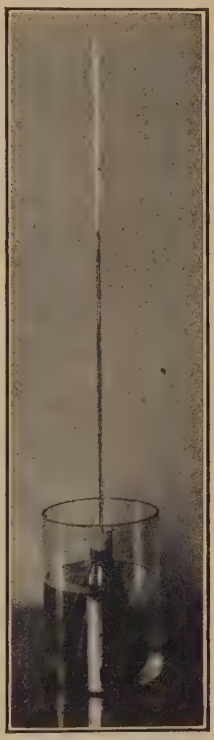
Problems — 1. Freezing and melting.
2. How ice cream is frozen.
3. Why we use ice in a refrigerator.
4. What happens when ice water is warmed?

Problem 1 — Freezing and melting

Home Problem. — Fill a small preserve jar with cold water. Fit a rubber ring to the top. Adjust the cover and clamp it down tight. Set the jar of water out of doors during a cold night. Examine the following morning. What happens? How do you explain this? Why do water pipes sometimes burst in winter? How can ice break off rocks from cliffs and mountain sides in winter? During warm weather you can perform this experiment as follows. *Fill a half-pint preserve jar* by holding it under water. Adjust the cover and clamp it down tight, keeping the jar under water while doing this. Fill a large pail with a mixture of chopped ice and salt. Bury the preserve jar in this mixture and keep it there until the water freezes. *What happens to the jar?* How do you account for this?

Class Problem. — (*a*) Hold a small piece of ice in the palm of one hand for a few minutes. What happens? What makes the ice melt? What change takes place? Why does the ice feel cold? Catch the water from the melting ice in a small dish. Set the dish over a flame for a few minutes. What happens to the water? What causes this change? Why does the water disappear? What are the three states of matter shown by these changes? Can you name any other substances that exist as a solid, a liquid, and a gas?

(*b*) Take a *clear* piece of ice with as few air bubbles as possible. Break it into small lumps. Drop these lumps into a small Erlenmeyer flask until it is about one-quarter filled. Add a few drops of red ink. Take a one-hole rubber stopper. Push one end of a piece of glass tubing, about two feet long, through the hole. Fill the flask brimming full of water from the tap. Insert the rubber stopper into the mouth of the flask and force it down so that the water rises inside the glass tubing nearly to the top. Mark the level of the water in the glass tubing with a piece of string. Now set the flask into a pail partly filled with warm water. *Watch the level of the water in the glass tubing.* What happens? What happens to the ice inside the flask? Explain why the water in the glass tubing goes down. When a cubic foot of ice melts, is a cubic foot of water formed? Why? Which is heavier, a cubic foot of ice or a cubic foot of ice water? Why does ice float? If ice were heavier than water, what would happen to ponds in winter?



What happens to the water column as the ice melts?

Very few liquids expand on becoming solid as water does. Nearly all metals, for example, occupy less space as solids than they do when melted.

Problem 2 — How ice cream is frozen

Class Problem. — Use a small standard freezer, with a wooden tub, of any reliable make. Bring from home tested

recipes of creams, ices, or sherbets. We suggest the following recipe.

> **Orange Water Ice.** — ½ pint of sugar, ½ pint of orange juice, ½ teaspoon extract of orange, 1 pint water, juice of one lemon. Boil sugar and water five minutes and cool. When cold, add orange and lemon juice and extract. Strain through a cheesecloth. This makes about one quart of ice. The juices of almost any berries or fruits may be used in place of the orange.

How to freeze the mixture. With an ice crusher or chipper cut a piece of ice into *very fine chips*. Be sure there are no large lumps of ice. Put about four quarts of chipped ice into a wooden box. Add a quart and a half of coarse salt. Mix thoroughly. Now pour the orange juice mixture into the freezer can until it is two-thirds full. Set the can in place inside the wooden tub. Put the dasher inside the can and adjust the cover. Pack ice and salt mixture around the can even with the top. Adjust the gear frame and crank. Now pack ice and salt mixture over the top of the can.

What is the use of each part of this freezer?

(Courtesy of Joseph Breck & Sons)

Keep the top of the can covered until the mixture inside is frozen. Be sure the drip hole on the side of the tub is kept open. Turn the crank for about five minutes. About three minutes should be sufficient time to freeze orange juice mixture properly. Then remove the gear frame and cover. Examine the orange ice in the can.

How does the quantity of ice compare with the quantity of mixture put into the can? *Why do we mix salt and ice to freeze ice cream?*

Fill a beaker two-thirds full of chipped ice. Push the bulb of a Fahrenheit thermometer down into the ice. What is the temperature? Now add salt to the beaker of ice until it is full. Mix thoroughly. Take the temperature of this mixture. What is the result?

What happens to the ice while the mixture in the can is freezing? What causes the ice to melt? Why do we use a metal can and a wooden tub? Why is it better to cut ice into fine chips? Will the mixture freeze as rapidly if the ice doesn't melt? Why?

Problem 3 — Why we use ice in a refrigerator

Class Problem. — (*a*) With an ice pick chop a narrow hole, about three inches deep, in a block of ice. Push the bulb of a Fahrenheit thermometer to the bottom of this hole, and pack fine pieces of ice around it. Read the temperature carefully. Now nearly fill a small beaker with chopped ice. Add water. Stir with the thermometer.

Read the temperature of the ice water. What is the temperature of ice? Of ice water? Is ice any colder than ice water? *Why is ice worth more than ice water for keeping a refrigerator cold, when both are at the same temperature*?

(*b*) Take two milk bottles, quart size. Into each bottle pour three glasses of tap water. Use a common drinking glass, filling it even full each time. With a file mark the water level in each bottle carefully. Pour out the water. If we should again fill the bottles to the marks we shall have the *same amount of water* in each flask. This is important.

Now set the two bottles on the table side by side. Into each pour two glasses, even full, of warm water. Take the temperature. The temperature of the warm water in each bottle should be the same.

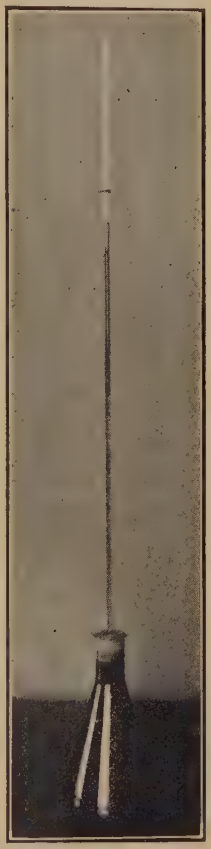
Into the first bottle pour ice water at 32° F. until the level of the water inside the bottle reaches the file mark.

Why is the water colder in one jar than in the other?

Shake. Take the temperature. Into the second bottle drop pieces of ice until the level of the water inside the bottle reaches the mark. Shake until all the ice is melted. Take the temperature. How many degrees does the ice water lower the temperature of the water in the first bottle? How many degrees does the ice lower the temperature of the water in the second bottle? How do you explain this? Is ice colder than ice water? How then can it cool the water more? Why is ice used in a refrigerator?

Problem 4 — What happens when ice water is warmed?

Class Problem.—Fill an Erlenmeyer flask with ice water at 32° F. To do this properly, first half fill a large jar or a water pail with chopped ice, and add enough water to cover the ice. Put in a little red ink to make the water more easily seen. Sink the flask in this mixture and stir until the water and the flask are both cooled to 32° F. Now empty the flask. Put a small piece of cheesecloth over the mouth to keep out pieces of ice and fill again with the ice-cold water. Push the rubber stopper firmly into the mouth of the flask so that the colored water rises inside the capillary tubing, nearly to the top. Be sure to exclude air bubbles. With mucilage fasten a narrow strip of paper along the side of the glass tubing. With a pencil, mark the level of the water in the glass tubing. Now set the flask on the table. Watch it for about ten minutes. At intervals of one minute mark the level of the water in the glass tubing. What happens as the water in the flask becomes warmer? Why does the column of water drop? Where does it go? What happens when ice water is warmed? *Now watch the water column carefully. Does it continue to drop?* Why does it stop, and then start to rise?



Notice how the water falls, stops, and then rises

What happens when warm water is cooled? When

ice water is warmed? When warm water at 100° F. is cooled to 32° F.? When water at 32° F. is warmed to 100° F.?

It has been discovered that the point at which this change in expansion and contraction takes place is approximately 39° F.

At what temperature will the flask full of water weigh the most? Which is heavier, water at 32° F. or at 39° F.? What is the temperature at the bottom of a pond in winter? Why doesn't ice form at the bottom?

PROJECT III

HOW WATER BOILS

Problems — 1. A study of boiling water.
2. Does water always boil at the same temperature?
3. How steam furnishes power.
4. The steam engine and how it works.

Problem 1 — A study of boiling water

Home Problem. — Pour about two quarts of water into a shallow pan. Heat slowly. Watch carefully until the water starts to boil. Report your observations the following day in class.

Class Problem. — Put a pint of clear cold water into a large beaker and heat slowly. Watch the first bubbles that appear. What are these? Where do they go? Where do they come from? Why does boiled water taste flat? How do fish breathe under water?

Let the water become hot. Watch the bottom of the beaker. What are these bubbles? Why do they form at the bottom? Why do they disappear before rising? What is the hissing sound? What is the singing of a tea kettle due to? As the water becomes hotter some of these bubbles rise a short distance and then disappear. How do you account for this? How can you tell when the water starts to boil? What are these bubbles? Why do they form at the bottom of the beaker? Why do they rise to the surface of the water before they burst? Is the steam in these bubbles visible? How do you know?

Partly close the gas cock so that the water boils slowly. Take the temperature. Open the gas cock and let the water boil

vigorously. Again take the temperature. Is water any hotter when it boils fast? Why?

Put three or four teaspoons of sugar into the boiling water. Why does the water stop boiling? What happens to the sugar? Let it boil again. Take the temperature. Which is hotter, boiling sirup or boiling water?

Problem 2 — Does water always boil at the same temperature?

Class Problem. — Half fill an Erlenmeyer flask with water. Heat until the water starts to boil. Let it boil vigorously for a few seconds to drive out the air. Remove the flask from the flame, and stopper immediately.

This boy would not believe it until he tried it

Support the flask in an inverted position and pour cold water over the bottom. *What happens?* Repeat several times. How was the air driven out of the flask in the first place? Notice the space above the surface of the water. What fills this space when the water boils? How does this affect the pressure? What then makes the water stop boiling after a few seconds? What happens to this steam when cold water is poured over the bottom of the flask? What fills the space now? How does this affect the pressure? Why does the water start to boil again?

Turn the flask right side up and remove the stopper. Why is it difficult to do this? With a Fahrenheit thermometer take the temperature of the water. Compare this with the temperature of water boiling in the open flask. Explain how greater pressure affects the boiling point. Less pressure.

Air pressure is greater on some days than on others. It is also greater at sea level than on a mountain top. Why is boiling water hotter on some days? Why is it impossible to cook potatoes in boiling water on the top of a high mountain? At high elevations, as in Denver, many people use "pressure cookers." What are these? Why are they used?

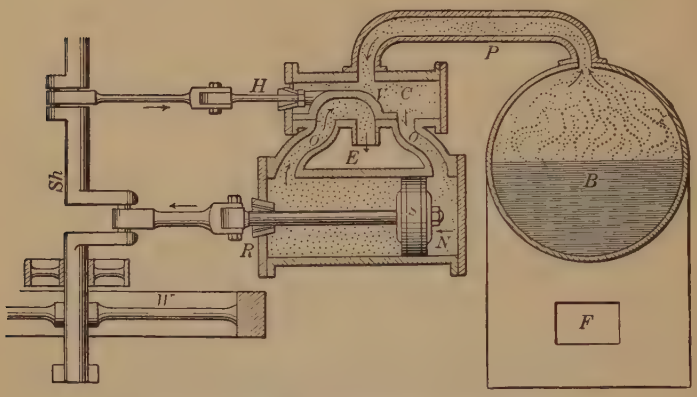
Problem 3 — How steam furnishes power

Class Problem. — Put three or four drops of water into a test tube. Push a cork stopper into the mouth. (*Caution.*—Do not force the stopper down too tightly.) Hold the test tube in a flame for a few seconds, using a holder. Keep the test tube at arm's length and pointing away from the body. *What happens?*

What causes the explosion? What drives the cork out? How much space did the drops of water take up? What happened when these drops changed to steam? Why was it impossible for the test tube to hold this steam? What caused the noise of the explosion? How can steam furnish power to drive a big locomotive?

Don't aim it at any one. It's loaded

Problem 4 — The steam engine and how it works



Can you explain how this steam engine works?

Class Problem. — Examine a toy steam engine. Locate the fly wheel, piston rod, cylinder, steam pipe, boiler, steam chest, water gauge, safety valve, and eccentric. Partly fill the boiler with water and heat it. Let the engine run for a few minutes. Where is the live steam found? Where does it go? Where does the exhaust steam come out? What makes the piston move back and forth? How does the safety valve work?

PROJECT IV

HOW WATER IS PURIFIED

Filtration and distillation are the two greatest processes of nature for purifying water. Much of the water that we use for drinking and cooking comes from the bitter, salty waters of the ocean. By nature's distillation this water is made fresh and pure. Perhaps you have drunk the clear sparkling water from a bubbling spring. This water has been strained through many layers of soil and made safe to drink.

Problems — 1. How water is made pure by filtration.
2. How water is made pure by distillation.

Problem 1 — How water is made pure by filtration

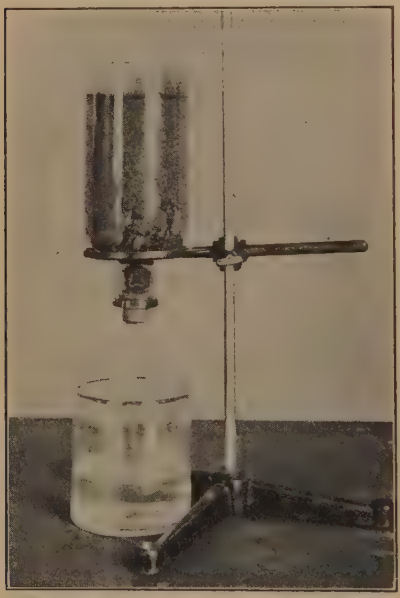
Class Problem. — (*a*) Fold a filter paper, and put it in a funnel supported by a ring stand. Place a glass under the funnel to catch the drip.

Now mix a spoonful of soil with a little water. Stir well, and pour the mixture slowly into the filter. Is the filtered liquid muddy or clear? Where is the soil?

(*b*) Wash the funnel and glass which you have just used, and set up the apparatus again, using a clean

Notice the clear water in the jar. What has become of the mud?

filter paper. Now add a spoonful of sugar to a little water in a glass. Stir well, and pour the mixture into the funnel as before. Taste the filtered liquid. Does it contain sugar? How did the sugar pass through the filter paper? Why did not the soil pass through the paper? What sort of substances can be separated from water by filtration? What substances cannot be separated from water in this way?



In making this filter, a large bottle was used instead of a can. The bottom has been cut off

Filters are not always made of paper. A thick bed of sand and gravel acts in the same way. Some cities use filters of this sort to purify their water supplies. The following experiment will show you how these filters work. With a nail, punch about a dozen holes in the bottom of a coffee can. At the bottom put a layer of gravel about an inch thick. Over this put a layer of fine sand, three or four inches thick. Both the gravel and sand should be washed several times and thoroughly cleaned by rinsing in clear water. Support the coffee can and set a beaker under it.

Make a muddy mixture of soil and water. Pour this into the top of the can. What happens? Examine the filtered liquid. Explain why it is clean. Where is the soil?

How is it separated from the water? How does natural filtration purify well water? Spring water? Do you use a water filter at home? Faucet filters are so small that they are worthless as filters; and they may be a distinct source of danger as they form a breeding place for disease germs.

Problem 2 — How water is made pure by distillation

Home Problem. — Dissolve a teaspoonful of salt in a quarter of a glass of water. Pour into a shallow pan. Heat until all the water disappears. Examine the bottom of the pan. What do you find? Where is the water? Why does it disappear? Why is the salt left?

Class Problem. — Arrange a simple still as shown in the illustration. Pour a small quantity of water into the flask. Add a teaspoonful of salt and a handful of garden soil. Heat slowly.

With this simple still you can get clean water from dirty water

Collect half an inch or more of water in the test tube. Examine. Does this water contain any soil? Taste it. Does it taste salty? How do you account for this? Where is the soil? The salt? Why does water come over into the test tube?

Explain why the salt and soil are left in the flask. Alcohol boils at a lower temperature than water. How can you separate them? The boiling temperature of ether is much lower than that of alcohol. How can you separate a solution of water, alcohol, and ether? How is it possible to use salt water for cooking on ocean steamers? How can pure rain water come from dirty mud puddles in the streets? Continued boiling makes maple sirup thicker. How do you account for this?

PROJECT V

PUMPS AND HOW THEY WORK

Problems — 1. Why water rises in a pipe.
2. The lift pump and how it works.
3. The operation of a force pump.

Problem 1 — Why water rises in a pipe

Class Problem. — Take an Erlenmeyer flask and a two-hole rubber stopper to fit. Push two pieces of glass tubing through the holes as shown at *A* and *B*. Let tube *A* extend nearly to the bottom of the flask. Half fill the flask with cold water and color with a few drops of red ink.

(*a*) Blow through glass tube *B*. Where does the air go? How does this affect the surface of the water inside the flask? What happens in tube *A*? What makes the water go up?

(*b*) Blow through glass tube *B*, forcing water nearly to the top of *A*. Quickly press a finger on the end of *B*. What holds up the column of water in *A*? Remove the finger. Why does the water in *A* drop back into the flask?

(*c*) Hold one finger on the top of *A*, and blow through *B*. Is water forced up *A*? Explain.

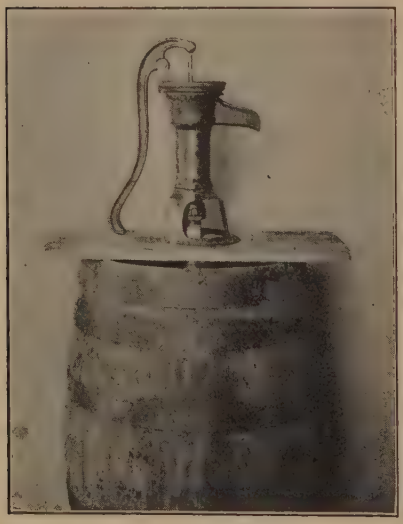
Blow through tube B and see what happens

(*d*) Blow through *A*. What makes the bubbles in the flask? Where does this air go? Now press one finger tightly on the end of *B*. Take a long breath and blow vigorously through *A*. Remove the mouth but continue to hold the finger on *B*. What makes water go up *A*?

(*e*) Hold the mouth over the end of *A* and suck. What becomes of the air in *A*? Why does the water rise in the glass tube?

Problem 2 — The lift pump and how it works

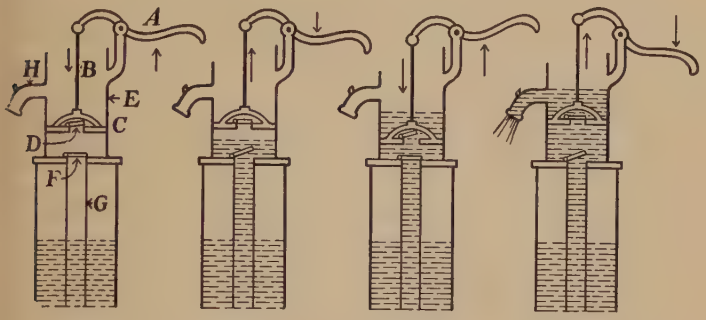
Class Problem. — Show how a real lift pump works. For this purpose use a kitchen lift pump. This may be purchased for a small sum from any hardware dealer. Pour three or four pails of water into a large pickle or vinegar barrel. Have a piece of galvanized iron pipe cut and threaded to fit the pump. This should be cut long enough to reach nearly to the bottom of the barrel. Bore a two-inch hole in the middle of a board, four feet long and a foot wide. Set this on top of the barrel. Screw one end of the iron pipe to the base of the pump. Pass the other end through the hole in the board, letting it extend into the water in the barrel.



You can have lots of fun studying a pump like this

Now show how the pump works. Why do you move the

handle up and down? Does water come out of the spout when you first start to pump? How do you "prime" a pump? What is the purpose of this? Raise the pump handle and hold it up. Why does the water run down?



1st stroke 2d stroke 3d stroke 4th stroke

This diagram shows how a lift pump works

A = handle	*C* = piston	*E* = cylinder	*G* = suction pipe
B = piston rod	*D* = piston valve	*F* = lower valve	*H* = spout

With a wrench take the pump apart and examine it. Describe the handle, piston rod, piston, piston valve, cylinder, and lower valve. Can you tell how each part works?

Show the operation of a lift pump from a glass model. First point out the cylinder, piston, piston valve, lower valve, and piston rod. Partly fill a glass jar with water, colored with a few drops of red ink. Hold the lower end of the glass pump in the water and move the piston up and down. *Watch the valves.* What happens when the piston goes up? When it goes down?

Empty all the water from the glass pump. Raise the piston to the top of the cylinder. Immerse the lower end of the cylinder in the water in the jar. At least four strokes of the piston are required to raise the water. *Watch carefully what happens as each stroke is completed.*

The 1st stroke. Push the piston down quickly. What happens to the lower valve? The piston valve? Where does the air in the cylinder below the piston go? What is the purpose of the first stroke?

The 2d stroke. Raise the piston quickly. What happens to the piston valve? To the air above the piston? What happens to the lower valve? What makes the water pass through the lower valve? What makes the water pass through the lower valve and partly fill the cylinder? How is this water forced up?

The 3d stroke. Push the piston down. What opens the piston valve? What closes the lower valve? What prevents the water from running out of the cylinder? What causes the water to pass through the piston valve above the piston?

The 4th stroke. Raise the piston again. What closes the piston valve? What makes water run out the spout? Why is this called a lift pump? What opens the lower valve? Why does more water pass through this valve from the glass jar? Why does this water fill the cylinder between the two valves?

Problem 3 — The operation of a force pump

The water supply of most large cities is pumped from lakes and rivers into huge tanks or reservoirs which are usually located on high hills. Farms and country homes frequently use force pumps, driven by gasoline engines or electric motors. Water is raised from wells or cisterns into large steel tanks. As water fills these tanks air is compressed. This compressed air forces water through pipes, furnishing a continual supply for houses and barns. Such a system is shown in the following experiment.

Class Problem. — Use a glass model force pump so that

you can see the action of the valves. For a tank take a small glass bottle with a wide mouth. Insert a two-hole rubber stopper and set it, inverted, on a ring stand. Connect the bottle with the force pump as shown in the diagram. Bend a long piece of glass tubing as shown at *C*. This represents the iron pipe that carries water to the bathroom or kitchen. For a faucet slip a short piece of rubber tubing over the end of *C* and close it with a clamp *D*.

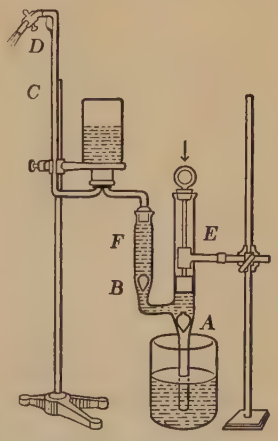


Diagram of a force pump. It raises water higher than a lift pump can

Partly fill a glass jar with water colored with a few drops of red ink. Push the piston down to the bottom of the cylinder *E*. *Now raise the piston slowly.* Watch valve *A*. What makes it open? Why does water rise into the cylinder *E*? *Push the piston down.* Why does valve *A* close? What causes valve *B* to open? Why does water rise into cylinder *F*? Raise the piston again. Why does valve *B* close? Explain why this is called a force pump. Move the piston up and down several times, until the glass tank is about a quarter full of water. What happens to the air in the tank when more water is forced in? When less water is forced in? *Open the clamp D.* What happens? Where does this water come from? What forces it up the pipe *C*? How does the quantity of water in the tank affect the pressure? Explain why water rushes out through *C* with greater force when the tank is nearly full.

PROJECT VI

THE SIPHON AND HOW IT WORKS

A siphon often comes in handy to transfer liquids from one container to another. The closet trap in your bathroom, and probably the flush tank, are siphons.

Problem 1 — How to use a siphon

Home Problem. — Cut off a length from an old garden hose about three feet long. Take two pails. Half fill one pail with water and set it in the kitchen sink. Hold one end of the hose under water in this pail. Suck on the other end until water starts to flow. Set the second pail on the floor and let the water run into it. Explain why sucking on one end of the hose starts the water. What makes it keep on flowing?

Have you ever seen water run up hill before?

Class Problem. — Take a piece of glass tubing a foot and a half long. Bend it in the shape of a U. Make one arm six inches long, and the other arm eight inches long. Fill a large glass jar nearly full of cold water and set it on a box. Lower the longer arm *A* of the siphon into the water. Let it extend nearly to the bottom of the jar. Suck at the end of the shorter arm *B*, until the water starts to flow. Let it run for a few seconds.

How does sucking start a siphon? Try to start it by the following method. Pour water into one arm of the siphon until it is full. Close the ends with the fingers. Invert and lower the longer arm into the water nearly to the bottom of the jar. Remove the fingers. *What happens?* Explain how sucking starts a siphon. Why is it necessary to remove the air from arm *A*? What forces water up arm *A* when air is removed?

Refill the jar with water. Lower the longer arm *A* into the water. Let it extend nearly to the bottom of the jar. Start the siphon by sucking. With a rule, measure the length of arm *A above the surface of the water*. Measure the length of arm *B*. Which arm is longer? Which arm holds more water? *Which then is heavier* — the water in arm *B*, or the water in arm *A* above the surface of the water in the jar? *Raise the siphon* slowly until the water stops flowing. Again measure the lengths of the two arms. How do they compare? How do the weights of water in the two arms compare? Explain why the siphon stops. Raise the siphon so that the open end of arm *A* is barely immersed in the water. Try to start it. Why does the siphon fill with water when you suck at the open end of arm *B*? In which arm is the column of water heavier now? Remove the mouth. What happens? Explain.

Put the shorter arm *B* of the siphon into the water in the jar. Start the water flowing. Compare the weight of the water in the two arms. In which arm is it heavier? Explain why the siphon works faster with the short arm in the jar.

PROJECT VII

WHERE OUR DRINKING WATER COMES FROM

Every possible precaution is needed to guard the purity of our drinking water. Many people die yearly from such terrible diseases as typhoid fever, dysentery, and cholera. Water may be clear and sparkling and still contain millions of the invisible germs of these intestinal diseases. These germs are thrown off in the filthy waste matter from the intestines of human beings. They are found in cesspools, privies, and streams containing sewage. In uninhabited regions the water supplied by nature is safe. Here we can drink without fear the cold clear water of forest springs and mountain brooks. From such regions water is brought for many miles to supply the people of some of our big cities. Our greatest dangers are found in the water from wells, springs, lakes, and streams which may be polluted by the wastes from human beings. To guard against these dangers every precaution is needed.

Problems — 1. How country homes are supplied with water.
2. How water is distributed.
3. The water supply of a big city.

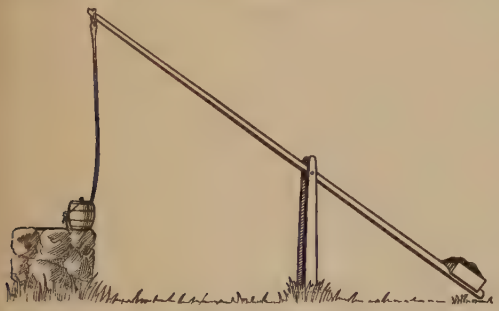
Problem 1 — How country homes are supplied with water

(NOTE. — If you live in a city or large town, apply this problem to some home in the country with which you are acquainted.)

Home Problem. — The old oaken bucket that hung in the well is, for the most part, a fond relic of bygone days. Although wells are still the principal sources of water for country homes, more convenient methods for carrying this

water have been found. Lift pumps are very common, but these are being replaced with pipe systems which carry a constant supply of water to barns and houses. Force pumps, driven by windmills, gasoline engines, or electric motors, pump water into elevated cisterns or into pressure tanks. (See problem, page 85.)

Location of well. Make a neat plan of your house, barn, barnyard, privy, cesspool, sink drain, and pig pen, to show the locations. Show the relative positions of these by small squares. Now draw a small circle to show where your well is located. Label everything. Draw several arrows near this circle, to show the downward slope of the land. In each square write a number indicating the distance in feet from the well. Pace off the distances from the well to the barn, house, cesspool, etc. Call a long step, three feet. Is your well at least a hundred feet distant from these places? Does the land slope toward the well from any of these places?



The old oaken bucket and "well sweep" of our grandfathers

Construction of well. Is it a driven well or a dug well? About how deep is it? Does it dry up in summer? How are the sides built? Are they built of stones? Are the holes between these stones filled with cement for several feet below the top of the well? Is the top of the well raised? Is it surrounded by a thick layer of cement? Is the top of your well open? Is it covered with boards?

Can dirty water leak through the cracks? Can worms, snakes, toads, or insects crawl through the loose stones and fall into the water? Can dirty water from the barnyard, sink drain, or ground surface drain into the well? Do you consider the water of your well safe to drink? Can you suggest any improvements?

Is your home supplied with running water? Do you use a pressure tank, or a tank placed on a high elevation? How is water forced into this tank? How is it carried to your house? Draw a simple plan to show how your home is supplied with running water. Label windmill, tanks, pumps, pipes, etc. If your home is not supplied with running water, can you draw a plan to show how a system could be installed?

Problem 2 — How water is distributed

The water supply of many towns and cities is pumped into big tanks and reservoirs, located on high elevations. The following problem will show you how water is distributed from these to homes at different elevations throughout the city.

Class Problem. — Set up the apparatus as shown in the illustration, using a large glass funnel, glass tubing, and rubber tubing. The end of the short piece of glass tubing at *E* has been drawn out by heating, to make a small hole. The entire apparatus should be about three feet in height. Let *A* represent a reservoir, located on a high elevation outside of a city. Let *B*, *C*, *D*, and *E* represent positions of cold water faucets in homes at different elevations in the city. The elevation of *E* can be changed by means of the piece of rubber tubing.

Let one member of the class pour water into *A*, keeping it full during the entire experiment. Use a pail to catch

the overflow at *E*. Lower *E* until the pipes are filled with water. Drive out all the air bubbles. Raise *E* until it is level with the top of *A*. Compare the levels of the water in *A* and *E*. How do you explain this?

This shows how water may be carried over hills and under valleys to your home

Lower *E* slowly until it is level with *C*. With *D*. Watch the jet of water at *E*. At which elevation does the jet have more force, at *C* or at *D*? How does the force of the jet vary as *E* is lowered? As *E* is raised?

With a ruler, measure the vertical heights of *AB*, *BC*, and *DE*. Which column of water weighs more, *AB* or *BC*? Will these two columns of water balance? Explain why water rises over *C*. Compare the weights of the vertical columns of water *AB* and *DE*. Why is the pressure or force of the water greater at *E* than at *C*? Why is the pressure greater at *D* than at *C*? Why is it greater at *B* than *E*?

Where is the water pressure in your house greater, in the basement or in the bathroom? What sections of your city have a high water pressure? Explain. What sections have a low pressure? Explain.

Problem 3 — The water supply of a big city

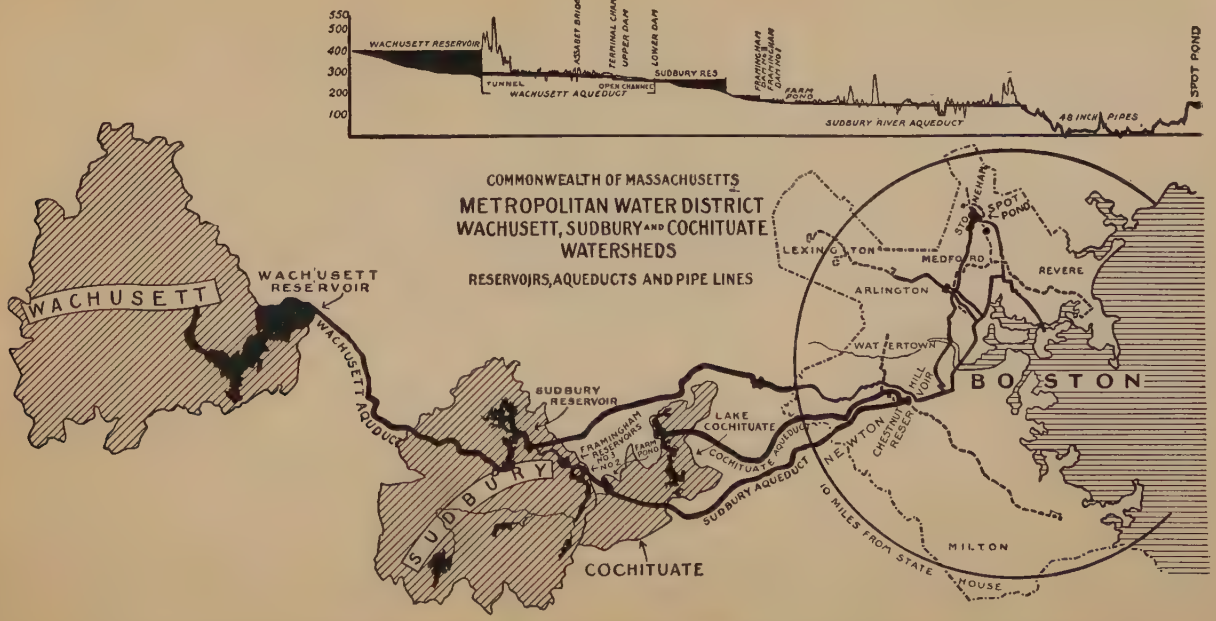
Home Problem. — Make a careful study of the map and elevation drawing, showing how the city of Boston, Massachusetts, is supplied with water.

Locate the Wachusett reservoir, Sudbury reservoir, Lake Cochituate, and the Chestnut Hill reservoir. Estimate roughly the distance of each of these from Boston. How are these reservoirs connected? What is the approximate length of each aqueduct? From the elevation drawing find the elevations of the Wachusett reservoir, Sudbury reservoir, Lake Cochituate, and the Chestnut Hill reservoir. What makes the water from the Wachusett reservoir flow into the Sudbury reservoir? What makes the water from the Sudbury reservoir and Lake Cochituate flow into the Chestnut Hill reservoir?

Locate Spot Pond. What is the elevation? What makes the water flow through the big pipes from the Chestnut Hill reservoir to Spot Pond? High tanks, called standpipes, are built on hills in West Roxbury, Quincy, Lexington, and Winthrop. How are these tanks filled? How do they supply the districts near them with water?

Class Problem. — What are the sources of the water supply for your city? Where are these bodies of water located? Why were these sources of water supply selected? What means are taken to insure the purity of this water?

Draw a large blackboard plan of your water system. Show the locations of the principal parts, such as rivers, lakes, reservoirs, standpipes, aqueducts, large pipe lines, and pumping stations. Label all parts. Copy this plan in your notebook. Now trace the course of the water from the sources of supply to your own home.



This is one of the greatest water systems of the world. It supplies water to more than a million people

Compare, if possible, the relative elevations of sources of supply, reservoirs, standpipes, and city buildings. Explain how the water flows through the different parts of the system. Are some of the city buildings on high elevations? How are these supplied with water? Explain how water is raised to the tops of some of the highest buildings in your city.

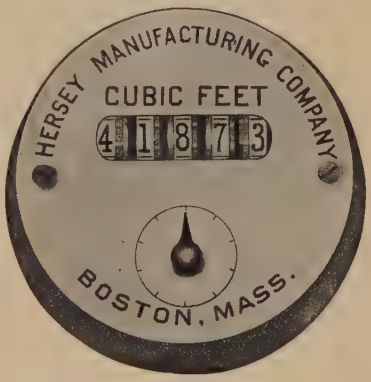
PROJECT VIII

THE COST OF WATER

Problems — 1. How water is sold.
2. How water is wasted.

Problem 1 — How water is sold

Water is usually sold by two methods: (1) At so much per year. (2) At so much for every 100 gallons. When water is sold by the second method, the quantity used is measured in gallons or cubic feet by a water meter. A cubic foot equals approximately $7\frac{1}{2}$ gallons.



A straight reading register
Courtesy of Hersey Manufacturing Co.

How to read a water meter. Meters register the quantity of water used in two ways: (1) The straight reading register. (2) The dial register.

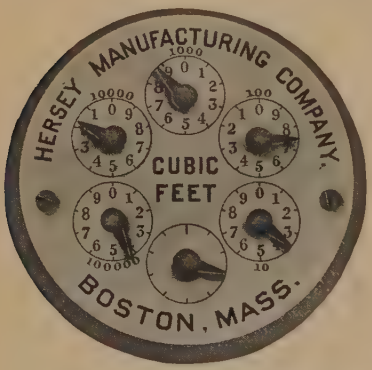
The straight reading register is a line of figures showing directly the number of cubic feet of water that has passed through the meter.

In order to read the dial register you will need to study the diagram and directions given below.

There are six circles in this dial. The lower circle is used only for testing. The other circles are labeled 10, 100, 1000, 10,000, and 100,000. Each number shows the total cubic feet registered by a complete revolution of the pointer. The pointer of the 10 cubic foot circle turns to

the right. The pointer of each higher circle turns in a direction opposite to the next lower. Each circle is divided into 10 equal divisions. One division of the 10 cubic foot circle registers 1 cubic foot. One division of the 100 cubic foot circle registers 10 cubic feet, and so on.

In reading, begin with the 10 cubic foot circle. Notice first the direction in which the pointer turns. Read the figure the pointer has last passed by. When a pointer is between two figures, the lower one must always be taken. When a pointer is so near a figure that there is doubt as to its reading, refer to the next lower circle. If its pointer has reached or passed the zero then the larger number should be taken. If it has not passed zero, the lower figure must still be taken.



A dial register. The reading is 41,873 cubic feet

Courtesy of Hersey Manufacturing Co.

In reading the above dial the pointer of the 10 cubic foot circle is between 3 and 4. So we read it 3. In the same way the reading of the next circle is 7, the next 8, the next 1, and the next 4. The total reading is 41,873 cubic feet.

How a water bill is made out. To estimate the quantity of water used for a given period, two readings of the same meter must be taken; one reading at the start of the period and the other reading at the end. The first reading is subtracted from the last.

Reading of meter on Jan. 1	=	56,500 cubic feet
Reading of meter on Apr. 1	=	54,000 cubic feet
Quantity of water used	=	2,500 cubic feet

At $2.00 per 1000 cubic feet, the total charge on this bill would be $2.00 × 2½ or $5.00.

Home Problem. — Locate your water meter at home. Does it have a straight reading register or a dial register? *Read this meter.* How many cubic feet of water does it register? What is the cost of 1000 cubic feet of water in your city? What is the total cost of water as registered by your meter? How many gallons of water do you get for one dollar? For ten cents? For one cent? If you use 30 gallons of water for a bath, how much does it cost?

What is the cost of water in your house for one week? Read the meter. At the end of seven days read it again. Record as follows:

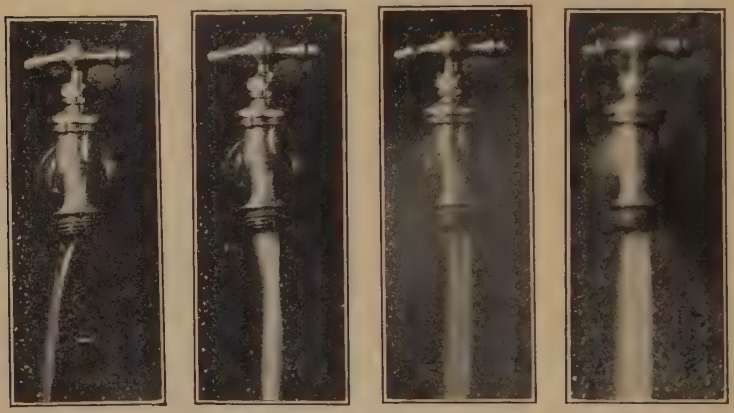
Last reading = cubic feet
First reading = cubic feet
Water used for one week = cubic feet
Rate = per 1000 cubic feet
Cost for one week =

Problem 2 — How water is wasted

Pure drinking water is supplied to you by your city at a great cost. On account of the carelessness of some people a considerable part of this water is wasted. It runs back into the sewer, unused, from leaking fixtures and open faucets. It is your duty as a good citizen to help save the water supply of your city.

Class Problem. — Estimate the cost of water wasted from leaking or open faucets as follows. Barely open the faucet and let the water drip rapidly. Hold a quart measure under the faucet, until it is quarter full. Time it, using the minute hand of a watch. Let water run from the faucet in a small stream. Hold the quart measure under this stream until it is full. Take the time. Open the faucet

halfway and let water flow in a medium stream. Hold a gallon measure under this stream. Fill it with water.



One gallon in six minutes | One gallon in one minute | One gallon in thirty seconds | One gallon in fifteen seconds

Leaking faucets cost money. Figure the cost of each of these for one week

Take the time in seconds. Turn the faucet on, wide open, letting water flow in a full stream. Fill the gallon measure as before. Take the time in seconds.

Record the results of your tests as follows. In the first column show the test made, in the second column the time in minutes and seconds for one gallon of water to run to waste, in the third column the total number of gallons wasted per year, and in the fourth column the total cost of this water.

Tests	Time for 1 Gallon	Waste per Year in Gallons	Total Cost per Year
Drip			
Small stream			
Medium stream			
Full stream			

Home Problem. — Examine the faucets and toilets at home for leaks. Estimate the cost of waste water per year. Report as follows.

	Total	How Many Leaking	How Many Perfect	Cost of Water per Year
Faucets				
Toilets				

Leaking faucets can usually be repaired very easily. First turn off the water at the shut-off. With a wrench loosen the faucet nut, and remove the top. In some faucets you will find a ball of hard rubber. In other faucets you will find either rubber or leather washers. These are probably worn out. Simply purchase new ones at any hardware store and replace them.

FACTS EVERY ONE SHOULD KNOW ABOUT WATER

Uses of Water. — Water is so common in the everyday experience of living, where we use it repeatedly for drinking, cooking, and washing, that we often fail to appreciate some of the less apparent contributions it makes to our well-being. Perhaps you know how much warmer it is in winter, and how much cooler in summer near the ocean or a big lake than it is in the interior of the country. Have you noticed how long it takes to heat a kettle of water on the stove? Did you ever take a hot water bottle to bed? Doesn't it take a long time for the water to cool off? Big bodies of water are like this. They heat slowly and cool slowly, thus making the climate of the surrounding regions more moderate.

Water is a great builder. It built many of the rolling hills of New England and the great lake region during the ice age, thousands of years ago. It builds fertile plains along the courses of rivers. It digs deep gullies and ravines in hills and mountain sides.

Water is a giant of tremendous power. When changed to steam it drives the wheels of factories and locomotives or the propellers of big steamships. The weight of falling water turned the old-fashioned mill wheels of our grandfathers. To-day we use the power of waterfalls to revolve great turbines, which, in turn, drive powerful dynamos. Electricity generated in this way can be sent hundreds of miles to heat and light big cities, or it can be stored in batteries to furnish power for automobiles. Only a small proportion of our falls have been harnessed in this way. Without doubt, enough water runs to waste to supply the world with heat, light, and power.

Composition of Water. — Water can be separated into its elements. It is a chemical compound made up of two parts hydrogen and one part oxygen. Hydrogen is a colorless, odorless gas. It is the lightest of all known substances. It burns with a very hot, blue flame, combining with oxygen of the air to form water again. You have seen toy balloons floating about in the air. These are usually filled with hydrogen. You even can buy this gas if you wish to, for it is stored in heavy steel cylinders, many gallons of gas being compressed in a very small space.

Oxygen is also a colorless, odorless gas. It is heavier than air. Oxygen does not burn, but it helps other things to burn. It keeps the fuel burning in our stoves at home, in our bodies, and under the boilers of steam engines. Oxygen is the most abundant element on the earth. As an uncombined gas it makes up about one-fifth of the air by volume. Combined with other elements it makes up about eight-ninths of water and one-half of solid rocks by weight. Large quantities of oxygen are compressed in steel cylinders and sold to hospitals for reviving sick people, to machine shops for welding steel, and to garages for burning carbon out of automobile cylinders.

Ice. — When liquid water freezes it changes to solid ice. When water evaporates it turns into an invisible gas. Water may be a liquid, a solid, or a gas. This is also true of other substances. Gases may be changed to liquids and solids, or solids to liquids and gases. Pure water changes to ice at 32° F. but when it contains impurities like salt it freezes at a lower temperature. As water cools from 212° F. it shrinks. If we fill a pail with warm water and let it cool, the water shrinks below the top of the pail. Now, at about 39° F. a remarkable thing happens. Water stops

shrinking. If it is cooled still more, the water swells or expands and rises in the pail again. This goes on until 32° is reached. At this temperature a much greater expansion takes place as the water changes to ice. When ice at 32° F. changes to water at 32° F. there is a sudden contraction, from 32° F. to 39° F. a gradual contraction, and from 39° F. to 212° F. a gradual expansion. Our water pipes and radiators at home sometimes burst in winter when water freezes in them.

Ice is lighter than water. It floats. When a pond starts to freeze in winter many interesting changes take place. As the warm water cools it contracts, becomes heavier, and sinks. Warmer water rises to the top, cools, and sinks again. This continues until the temperature of all the water in the pond is 39° F. As the water cools below this temperature it expands and becomes lighter. Therefore it floats and freezes when the temperature drops to 32° F. If this change did not take place, ponds and lakes would freeze solid during cold winters and the heat of summer would be insufficient to melt all the ice.

Did you ever wonder why ice feels so cold? It takes a lot of heat to melt it. And the funny thing about it is this. When a cake of ice changes to water, the water is just as cold as the ice. All the heat was used up to melt the ice. It has been found that it takes about 45 times as much heat to melt a cubic foot of ice as it takes to raise the temperature of an equal weight of water 1° F. This explains why ice keeps the food in our refrigerators cold in summer.

Steam. — Have you ever watched a kettle of cold water come to a "boil"? The first bubbles that you see are filled with air. Water dissolves many gases such as air. This is the air that fishes and water plants use for breathing.

As the water in the kettle becomes hotter you will notice bubbles form at the bottom and then suddenly collapse, making a singing sound. These bubbles are filled with steam. They form at the bottom of the kettle first because it is hotter there. They collapse because the colder water above condenses the steam and changes it back into water.

The singing sound is produced when the water in the bubbles hits the bottom of the kettle with little taps as the bubbles collapse. Watching these bubbles of steam, you will see them rise higher and higher until they burst through the surface, and we say the water boils. When steam first escapes from these bubbles it is invisible, but soon it condenses into thousands of tiny droplets of water which float in the air. The white cloud above a kettle of boiling water is formed in this way.

Some people think that one kettle full of boiling water is just as hot as another. This is not true. Boiling water is hotter on some days than on others, depending on the pressure of the air. When you inverted a flask of boiling water you noticed that the water stopped boiling, but when you poured cold water on the bottom of this flask it started to boil again. Cold water simply caused the steam to condense, forming a partial vacuum in the flask. This reduced the pressure on the surface of the water and it began to boil again. Reduced pressure lowers the boiling point while a greater pressure raises it. Since air weighs less on a top of a high mountain, the pressure is less. For this reason it is difficult to cook potatoes, because the water boils considerably below 212° F. Pressure cookers are used in some homes to-day. These are large kettles with tight-fitting covers which hold in the steam, thus producing more pressure on the surface of the water. This raises

the boiling point above 212° F., and of course meats and vegetables cook much quicker.

When water changes to steam it has tremendous power. This power is caused by expansion. A single quart of water will make nearly 1600 quarts of live steam. It is this tremendous pressure, caused by expanding steam in the cylinder of a locomotive, that pushes the piston back and forth.

Filters. — Nature uses for the most part two methods to purify water, filtration and distillation. Water passes through layers of sand and gravel which strains out the solid particles of dead and living matter. For this reason water from deep driven wells and protected springs is usually safe to drink. Some cities build artificial filters to remove impurities. The water supply of Lawrence, Massachusetts, is taken from the Merrimac River after it receives the sewage from two large cities, Lowell and Manchester. This water is filtered through beds of sand and gravel and made safe for drinking.

Rain, the purest of all natural water, is distilled water. It may come from salt lakes, the ocean, muddy streets, or rivers carrying filthy sewage. When it passes into the air, harmful impurities are left behind, because these do not evaporate.

Water Supply. — Early man drank water wherever he found it, from brooks, springs, lakes, or rivers. It was all safe. The Indians and most of the pioneers secured water in this way. As small communities were established, wells were dug near the kitchen door. This was found to be more convenient than carrying water from springs or rivers. Furthermore the waters of near-by streams were often unsafe to drink for they frequently received impurities from sink drains and privies. As these small communities grew

into large cities, well water became insufficient and in danger of contamination. Cities were compelled to secure their supply of water from large bodies of fresh water, usually located at a considerable distance. New York City brings her water from streams and lakes in the Catskill mountains, 100 miles away. The cities of Chicago, Cleveland, and Buffalo take theirs from the Great Lakes. Water for Los Angeles is carried by a huge pipe from distant mountains. The development of Boston can be traced by the growth of its water supply. As the population of the city increased, it became necessary to go farther and farther away to obtain an adequate supply of water. Most of it now comes from the great Wachusett reservoir located at a distance of about 40 miles from the city.

Pure Water. — The great problem to-day is to secure an adequate supply of safe water. Some people think that if water is only clear and cold it must be good to drink. This is wrong, for clear sparkling water may contain millions of the microscopic germs of disease. Typhoid fever kills over 20,000 people every year in the United States. The germs of this disease are so small that you cannot see them with the naked eye, but under a powerful microscope you can easily see them. They are oblong in shape with a cluster of fine hairs at either end. Typhoid fever is an intestinal disease. The germs are given off only in the waste from the large intestine. For this reason water supplies should be protected from human waste. Shallow wells are especially dangerous. They frequently receive the drainage from cesspools, sink drains, barnyards, or privies. There are no simple tests to tell you whether or not water is fit to drink. You can warm a little in a clean tin cup and smell of it. If it has a disagreeable odor it

is probably bad. The best thing to do is see that your water supply is protected from all contamination. Boil all suspicious water. This kills the germs of disease.

Plenty of good drinking water, together with plenty of nourishing food and plenty of fresh air, are three essentials for a strong healthy body. Of these three, water is the most important. Air suitable to breathe must contain water. Our food contains water, and we must have water to drink. In our bodies water performs many services. It helps to build bone, blood, and tissue. It carries digested food to all parts of the body. It carries away poisonous waste materials, and throws them off through the skin and kidneys. In addition to this, water helps to regulate the temperature of the body, as we shall learn in the next chapter.

CHAPTER IV

WEATHER AND ITS CHANGES

WEATHER is always with us, and always changing. It is usually the first thing we notice when we get out of bed in the morning. Perhaps the morning is a beautiful one, with bright sunshine, clear blue skies, and cool invigorating air. It may be hot and sultry, with still, damp air, that takes away our energy to work or play. The sun and blue skies may be hidden by dark clouds and we hear the "swish" of snow or the patter of raindrops. Perhaps we are suddenly awakened by a loud crash of thunder from a passing shower. These are only a few of the many changing conditions of the air which we call weather.

To some of us weather seems erratic. Yet it is governed by settled laws. There is a reason for every breeze that blows, every drop of rain that falls, and every cloud that floats in the sky. Perhaps you will discover some of the important reasons for changes in weather conditions in this chapter. To understand these changes, you will need to learn some facts relating to temperature, pressure, winds, the weather map, weather observations, and the two great processes known as evaporation and condensation.

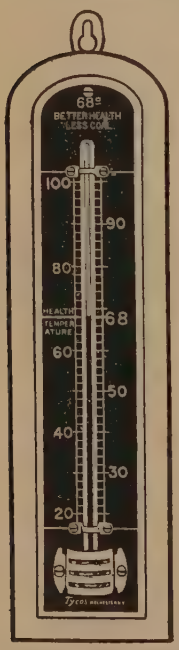
PROJECT I

THE THERMOMETER AND HOW IT WORKS

Problems — 1. How a thermometer is made.
2. How a thermometer indicates temperature.

Problem 1 — How a thermometer is made

Home Problem. — Examine a thermometer at home. How is it made? What substance is used in the bulb? Why is this substance used? Examine the bore. Why is it so small? Why is the top of the glass tube closed? How was it closed? What are the short straight lines? Why are these the same distances apart? What are the figures beside the lines? How do you read this thermometer? How should you hold the eye in reference to the top of the mercury column? What is the temperature for freezing? For boiling?



What does this household thermometer read?

Class Problem. — (*a*) *How a thermometer works.* Partly fill one glass beaker with warm water and another with cold water. Hold the bulb of a thermometer first in the warm water and then in the cold water. Watch the mercury column. What happens? What causes this movement of the mercury column?

(*b*) Fill an Erlenmeyer flask with cold water. Color the water with a spoonful of black ink. Take a piece of glass tubing, two feet long. Push one end through the hole in a rubber stopper. Press the stop-

per firmly into the mouth of the flask. Heat the water slowly. Why does water rise in the glass tubing? Is the flask still full of water? What effect does heat have on the water in the flask? Let the water in the flask cool. What happens? How do you account for this?

What makes the mercury column of your thermometer rise? What makes it drop? How does the size of the bore affect this rise and fall? The size of the bulb? The quantity of mercury?

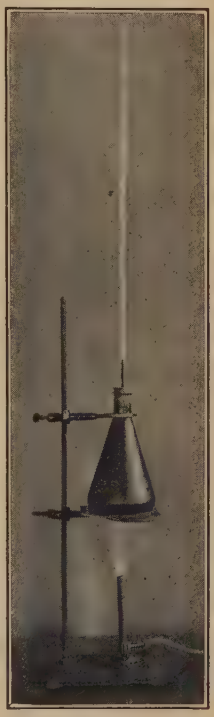
Problem 2 — How a thermometer indicates temperature

Class Problem. — Use a ground glass ungraduated thermometer for this experiment. Can this thermometer tell you how hot or cold it is? Why?

How to mark a scale on this thermometer. What is the temperature of melting ice? Of boiling water? What two fixed points of the scale can you determine then?

To locate the freezing point. Half fill a beaker with finely chopped ice. Immerse the bulb of the ungraduated thermometer in the ice and hold it there until the mercury stops falling. Locate the top of the mercury column. Make a straight line with a lead pencil to mark this point. What shall we call this temperature?

To locate the boiling point. Heat a beaker of water until it boils. Immerse the bulb of the ungraduated

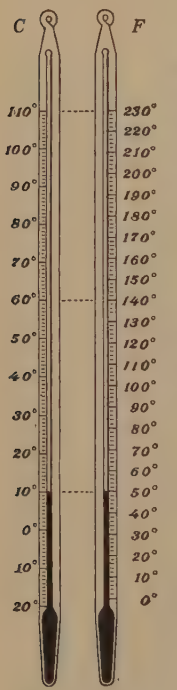


Watch the water rise in the tubing. Does the flask remain full?

thermometer in the boiling water. Locate the top of the mercury column. Make a straight line with a lead pencil to mark this point. What shall we call this temperature?

(NOTE. — This point may not be exact on account of elevation, atmospheric conditions, etc.)

Complete the scale for a Fahrenheit thermometer. Make a straight line with a lead pencil for every ten degrees between 32 and 212 in this way. Divide the distance between the freezing point and the boiling point into 18 equal parts by drawing 17 lines between the two that you already have. Label each line with its proper number, 42, 52, and so on.



Compare the two scales

The Fahrenheit scale is in common use in this country and in England.

Two other scales are used in different European countries; and one of them, called the Centigrade scale, is used in much of the more important scientific work in all countries.

On the Centigrade thermometer the freezing point is called 0°, and the boiling point is called 100°.

How many degrees are there between the freezing and boiling points on a Fahrenheit scale?

On a Centigrade scale?

Is a Centigrade degree greater or less than a Fahrenheit degree?

PROJECT II

THE BAROMETER AND HOW IT WORKS

Problems — 1. How air pressure is measured.
2. The aneroid barometer and how to read it.

In a previous chapter we found out that air is a real substance and that it has weight. The weight of the air changes from day to day, and these changes tell us when fair weather or storms are coming. The instrument that measures the weight of air is called a barometer.

Problem 1 — How air pressure is measured

Home Problem. — Fill an ordinary drinking glass brimming full of water. Cover with a thin piece of cardboard. Invert the glass. What keeps the water from running out?

Can you do this without spilling the water?

Class Problem. — How to make a barometer. Take a piece of glass tubing three feet long, which is sealed at one end. It should be about a quarter of an inch in diameter. Insert a small funnel into the open end and pour mercury slowly into the funnel. Do not hold the glass tubing in a

vertical position. The mercury may break the glass when it strikes. Keep the glass tubing inclined as much as possible, and fill with mercury. Take care that all air bubbles are excluded. Now pour about an inch of mercury into a small cup. Press one finger firmly over the open end of the glass tubing and invert it into the mercury in the cup. Remove the finger, taking care that the open end is well submerged. Support the glass tubing in a vertical position with a ring stand and clamp.

What is the reading of this barometer?

What holds the mercury up the tube? Where is this pressure exerted? Why did the mercury column drop a little when you removed your finger? What is the space above the mercury column? With a yard stick, measure carefully the height of the mercury column from the surface of the mercury in the cup. What determines the height of this column? *Air is heavier on some days than on others.* How does this affect the height of the mercury column?

Will the mercury column stand higher at sea level or on top of a high mountain? Tie a piece of black thread around the glass tubing at the top of the column of mercury. Look at it occasionally for several days. Does the height

of the mercury column change from day to day? What does this prove?

Problem 2 — The aneroid barometer and how to read it

Aneroid barometers are more convenient than mercury barometers. They consist of a metal case inclosing a small circular box of German silver, from which the air has been exhausted. The metallic sides of this box are very thin. As air pressure increases or decreases, these sides are forced nearer together, or separate. A spring and a system of levers are fastened to one side of this box These cause a pointer to swing back anb forth over a scale graduated in inches to correspond with the readings of a mercury barometer.

An aneroid barometer. Read it

Class Problem. — Examine an aneroid barometer. Point out the parts that you can see. Notice the two pointers. Turn the brass knob. What happens? What is the purpose of this pointer? In which direction does the long pointer turn when the pressure of the air increases? When it decreases?

How is the dial of an aneroid barometer marked? What is the largest number given on the dial? What is the smallest number? What do these numbers mean? Why is this barometer read in inches of pressure? Into

how many divisions is each inch divided? What is the reading of each division?

Practice reading an aneroid barometer as follows: With the brass knob turn the short pointer at different positions on the dial. Read the barometer as indicated by each of these positions.

(NOTE. — In actual practice this pointer is not used for reading.)

Draw the dial of the school barometer. Place the long pointer in any position you wish in your drawing. Record the reading as indicated.

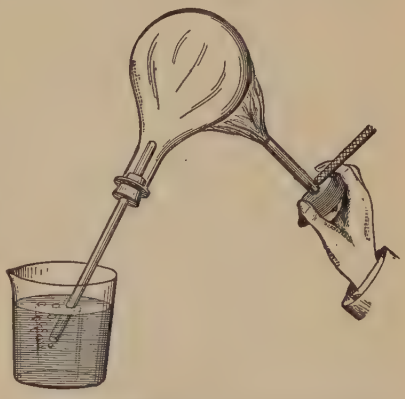
PROJECT III

WINDS AND WHERE THEY COME FROM

Problems — 1. How heat affects air.
2. Is cold air heavier than warm air?
3. Why winds blow.
4. How to tell the directions of winds.

Problem 1 — How heat affects air

Home Problem. — Wind a dish towel around the lower half of a quart milk bottle. Invert the bottle and set it in a wash basin. Pour about an inch of cold water into the basin. Now pour hot water over the dish towel. What happens? What are the bubbles? Where do they come from? Why are these bubbles forced out of the milk bottle?



Notice the bubbles in the jar. Where do they come from?

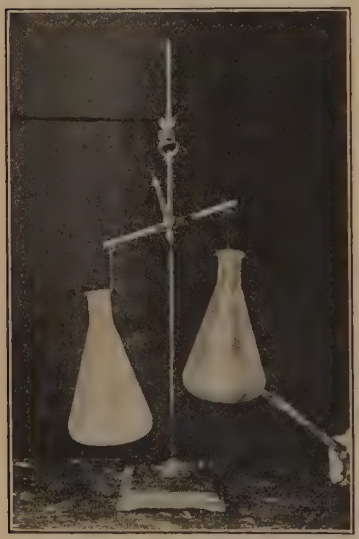
Class Problem. — Take a short piece of glass tubing. Push one end through the hole in a rubber stopper. Press the stopper firmly into the mouth of an Erlenmeyer flask. Partly fill a small glass jar with cold water. Invert the flask and hold the open end of the glass tubing under water in the jar. Heat the outside of the flask with the flame of a Bunsen burner. Take care not to hold the flame in one spot. Move it over the surface of the flask quickly.

What are the bubbles? Where do they come from? Is the flask still full of air? Why is some of the air forced out? How does heat affect air?

Keep the flask inverted for a few minutes, and let the air cool. What happens? Why does water rise into the flask? How high does it rise? Explain. How does cold affect air?

Problem 2 — Is cold air heavier than warm air?

Class Problem. — Take two large Erlenmeyer flasks (1000 c.c.) of the same size and shape. Select two of the same weight, if possible. Twist a short piece of fine wire around the neck of each flask. To this attach a loop of fine wire about three inches long. Suspend each flask by this loop from an arm of a sensitive balance. If one flask is lighter than the other, put fine sand into it until it balances. Heat one flask with the flame of a Bunsen burner, moving it over the surface quickly and evenly to avoid cracking the glass. What happens? Which flask is heavier? Let the flask cool again. What is the result? Heat the other flask. Which is heavier now? What do these flasks contain? How does heat affect this air? Why is cold air heavier than warm air?



Both flasks of air weighed the same at the start. Which weighs the most now?

Problem 3 —Why winds blow

Class Problem. — Make a wooden box, twelve inches long, four inches wide, and three inches high. All joints should be tight. Plane the edges of the boards smooth and spread on a layer of soft putty before nailing. Cut two circular holes, two inches in diameter, in the top of the box, one near each end. Set two paraffin candles directly under one of the holes and light them. Place a tall lamp chimney over each hole. Drop melted paraffin around the base of each chimney to seal it tightly. Label the lamp chimney over the burning candles *A*. Label the other lamp chimney *B*.

Watch the smoke go down one chimney and up the other

Light a large wood splint. Let it burn for a few seconds. Blow out the flame. Now hold the end of the smoking splint directly over the top of chimney *B*. Repeat several times. Watch the smoke. How does it go in chimney *B*? In chimney *A*? How does the air in chimney *B* move? In chimney *A*? In which direction does the air inside the box move? How do the candle flames affect the air in chimney *A*?

Which column of air is heavier, in chimney *A* or in chimney *B*? Explain why the air in *A* rises. Why does air go down chimney *B*? Why does it move toward chimney

A inside the box? What would happen if we put the lighted candles under chimney *B*?

Show the similarity between this circulation of air and winds. What takes the place of the burning candles? What happens when the sun heats any section of the country more than the surrounding regions? What happens to the air over the heated section? Over the surrounding regions? In what direction will the wind blow?

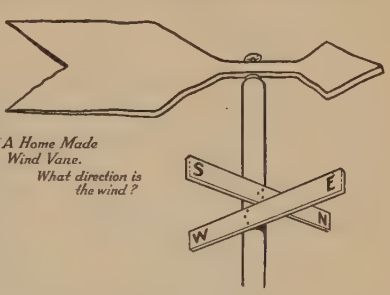
Problem 4 — How to tell the directions of winds

Home Problem. — Locate a wind vane near your home, or on your way to school. You will probably find one on some church spire, engine house, public building, or barn. Try to tell the direction of the wind by this vane. From what direction does a north wind come? A south wind? An east wind? A west wind? In what direction does a north wind go? A south wind? An east wind? A west wind? Why are north winds usually colder than south winds? Can you tell what winds usually bring fair weather? Stormy weather?

Make a small wind vane at home and set it up. Take a pine shingle, four or five inches wide, and whittle it out in the shape of an arrow. Use the thick end of the shingle for the head of the arrow. The tail of the arrow should be longer and broader than the head. Make the neck of the arrow about half an inch in width. Now put one finger under the neck of the arrow and find where it balances. It may be necessary to whittle a little more off the head or tail. Drive a small thin nail through the neck of the arrow at the point where it balances. Take care not to split the shingle. For an upright use a narrow wooden stick, three or four feet long. A broom handle works well for this purpose. Drive the point of the nail into the end of the

wooden stick. Spin the arrow around several times until it turns easily.

Your wind vane is now completed. Fasten it securely to a pole or the top of a building where the winds have a free sweep. To tell the direction of the wind with this vane you must first determine the principal points of the compass: north, south, east, and west. You can locate these points from the north star, the sun, or with a compass.



A Home Made Wind Vane. What direction is the wind?

If you stand facing the sun at noonday, at just twelve o'clock, and stretch out your arms, you will be facing the south; north will be back of you; your left hand will point toward the east, and your right hand will point toward the west.

PROJECT IV

WEATHER OBSERVATIONS AND HOW TO TAKE THEM

Problem 1 — How to keep a daily record of the weather

Class Problem. — Keep a daily weather record in your notebook for one month. Hang a Fahrenheit thermometer outside the building in a sheltered location, where the sun will not shine on it. Barometer readings may be taken indoors. Make all observations at the same time each day. A permanent record should be kept on a blackboard for constant reference. This record will also be used in a later problem. Try to account for any changes in the condition of the weather. Record as follows.

WEATHER OBSERVATIONS TAKEN AT 9:30 A.M.

DATE	TEMPERATURE	PRESSURE	WIND DIRECTION	CONDITION
Oct. 2	*64° F.*	*30.20 in.*	*N.W.*	*Fair*

PROJECT V

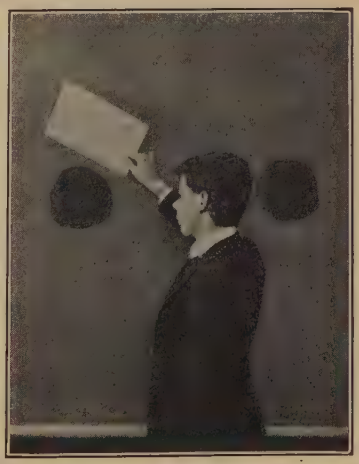
HOW AIR TAKES UP WATER

Problems — 1. Evaporation and how it goes on.
2. How evaporation keeps us cool.
3. How the amount of water in the air is measured.

The invisible water of the air is one of our best friends. Without it there would be no rain. Plants would wither and die. Man himself would soon perish for lack of food. Evaporation serves as a safety valve for the body, for it regulates the body temperature and keeps it constantly the same. We perspire freely on hot summer days or when we work hard. It is the evaporation of this perspiration that cools us, and prevents the body from becoming overheated. Evaporation is also used to make ice in summer and to keep cold storage plants cold.

Problem 1 — Evaporation and how it goes on

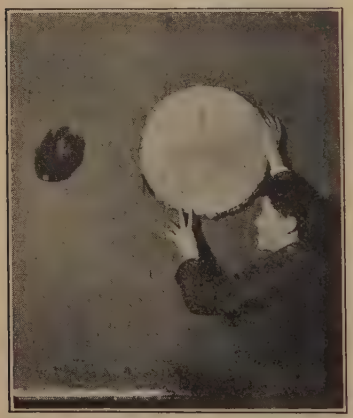
Home Problem. — Breathe on a cold mirror. Watch the moisture disappear. Where does it go? Can you see it go? What changes take place when this moisture disappears? When wet clothes are hung on a line to dry, what happens to the water? What is the process called? How does dew



Which spot disappears first?

on the grass disappear? Why do wet streets dry after a rain?

Class Problem. — (*a*) *Does wind help evaporation?* Wet a sponge and then wring out most of the water. Make a circular wet spot on the blackboard about a foot in diameter. Make a second wet spot like the first one at a distance of about four feet. Fan one of the spots with a piece of cardboard. Which spot disappears first? Why do clothes dry better on a windy day? Why do you blow on wet ink to dry it?



When one spot dries, take down the hoop and look at the other

(*b*) *Does heat help evaporation?* Warm a small section of the blackboard by holding an alcohol or gas flame against it. Make a circular wet spot on the heated section of the blackboard. Make a similar wet spot at a distance of about four feet. Which spot disappears first? Why do wet clothes dry faster in the sun? When hung near the kitchen range? When you press them with a hot iron?

(*c*) *Does dry air help evaporation?* Take a wooden barrel hoop. Cut out a circular piece of cloth to fit. Lay this over one side of the hoop and tack it evenly around the rim. Draw the cloth tightly to prevent it from sagging. Now moisten the cloth with water but do not make it dripping wet. With the sponge make two circular wet spots on the blackboard, about five feet apart. Keep one spot covered with the barrel hoop. Over which spot is the air drier? Which spot disappears first? Why do clothes dry

faster on some days than on others? How does the quantity of water in air affect the rate of evaporation?

(*d*) *Do all substances evaporate at the same rate?* Make one wet spot on the blackboard with water. Soak a small piece of cloth with ether, and with this make a second wet spot. Which spot disappears first? Which evaporates faster, ether or water? When you are doing this experiment, be sure that there is no flame anywhere in the laboratory. Do not light a match. See that no gas is burning.

Problem 2 — How evaporation keeps us cool

Home Problem. — Fan your face with a sheet of paper. How does it feel? Is the air cooler? Moisten the back of your hand with your tongue. Blow on it. What happens to the water? Is the air from your lungs cold? What then causes the sensation of coolness?

The glass is frozen to the box. Try it

Class Problem. — Take a wooden packing box, about a foot each way. Pour quarter of a glass of water on one side of this box, making a shallow pool. Set a small glass beaker on the box in the pool of water. A tin can may be used in place of the beaker. Pour half an inch of ether into the beaker. Put one end of a piece of glass tubing in the mouth and the other end in the ether. Blow through it

vigorously for three or four minutes. Now lift the box by taking hold of the glass beaker.

Why does the beaker freeze to the box? What happens to some of the ether when you blow into it? Evaporation absorbs heat from surrounding objects. Explain how the evaporation of ether makes water freeze. Which evaporates quicker, water or ether? Why is evaporating ether colder than evaporating water?

Problem 3 — How the amount of water in the air is measured

You have noticed how water passes into the air by evaporation, changing from a visible liquid to an invisible gas. The varying amounts of this invisible gas in the air can be measured by a simple instrument called a *hygrometer*. This instrument consists of two thermometers, attached to a board. A piece of fine muslin, which is kept wet with water, is wrapped around the bulb of one of them.

Class Problem. — (*a*) Take two Fahrenheit thermometers. Wrap a single thickness of fine muslin around the bulb of one thermometer. Tie it at the top and bottom with a piece of thread. Wet the muslin with water. Call this the wet bulb thermometer. Call the other the dry bulb thermometer.

Take the reading of the dry bulb thermometer in degrees Fahrenheit. With a piece of cardboard fan the muslin of the wet bulb thermometer, watching the mercury column at the same time. When it reaches the lowest point take the reading in degrees Fahrenheit.

Record your readings as follows: Subtract the wet bulb reading from the dry bulb reading.

Dry bulb reading, —— degrees
Wet bulb reading, —— degrees

Difference, —— degrees

Consult the Relative Humidity Tables on page 126. The readings of the dry bulb thermometer are given in the left-hand vertical column. In the horizontal line at the top, you will find numbers from 1 to 17. These numbers show the difference in degrees between the wet and dry bulb readings. The numbers in the other columns express different relative humidities in per cent. The following example will show you how to find the relative humidity.

Dry bulb reading, 73 degrees
Wet bulb reading, 61 degrees
Difference, 12 degrees

First find 73, the dry bulb reading, in the left-hand vertical column. Next find 12, the difference in degrees between the wet and dry bulb thermometers, in the horizontal line at the top. At the right of the number 73 is a horizontal row of figures. Directly below the number 12 is a vertical column of figures. At the intersection of these two rows of figures you will find the number 50. The relative humidity is 50 per cent. This means that the air contains half as much water as it could possibly hold at this temperature. In the same way, a relative humidity of 75% means that the air is three-fourths full of water; a relative humidity of 30% means that the air is three-tenths full of water, while a relative humidity of 100% means that the air contains all the water it can hold at that temperature.

From the same tables, determine the relative humidity of the classroom from your own readings. Repeat your

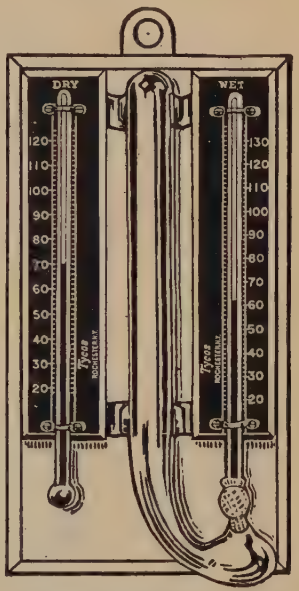
Relative Humidity Table

Difference in Degrees between Wet and Dry Bulb Thermometers

Reading of Dry Bulb Thermometer	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
45	93	86	79	71	65	58	52	45	39	33	26	20	14	8	2		
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4		
47	93	86	79	73	66	60	54	47	41	35	29	23	17	12	6	1	
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3	
49	93	87	80	74	67	61	55	49	43	37	32	26	21	15	10	5	
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2
51	94	87	81	75	69	63	57	51	45	40	35	29	24	19	14	9	4
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6
53	94	88	82	75	70	64	58	53	47	42	37	32	27	22	17	12	7
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9
55	94	88	82	76	71	65	60	55	49	44	39	34	29	25	20	15	11
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12
55	94	88	83	77	72	66	61	56	51	46	41	36	32	27	23	18	14
58	94	88	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15
79	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38

experiment out of doors and determine the outside relative humidity. How do the inside and out-of-door relative humidities compare? Which air is drier? How do you account for this?

(*b*) *Examine a Mason's hygrometer.* Describe it. Fill the water cup with clean water. Hang the instrument in a convenient place in the science room. Relative humidity charts always come with each instrument. Tack one of these on the wall where you can consult it. Let each member of the class determine the relative humidity with this instrument. Simply fan the wet bulb for a few moments. Take the readings of the dry and wet bulb thermometers. Subtract these two readings. From the chart find the relative humidity as previously directed.



A Mason's hygrometer. It measures relative humidity

PROJECT VI

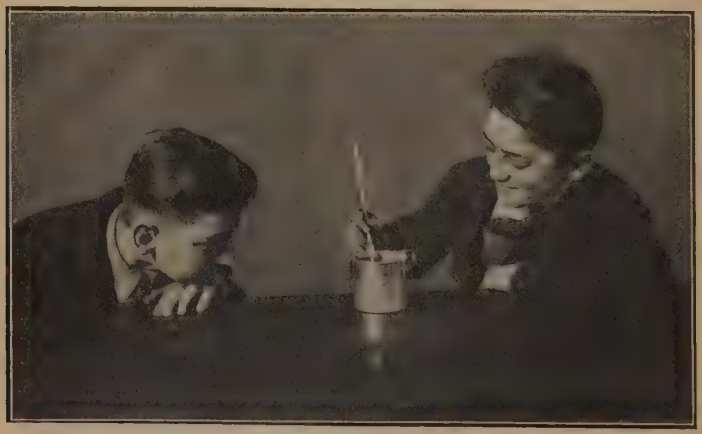
HOW WATER COMES OUT OF THE AIR

Problems — 1. A study of condensation.
2. Why it rains.

Problem 1 — A study of condensation

Home Problem. — Examine the outside of a pitcher of ice water. What do you find? Where do these drops of water come from? Why do they form on the outside of the pitcher? What is this process called?

Class Problem. — (*a*) *How to take water out of the air.* Half fill a bright tin cup with chopped ice. Add a handful



When a mist shows on the outside of the cup, read the thermometer

of salt. Stir the mixture. Watch the outside of the cup. What happens? Where do these drops of water come from? How does the cold cup affect the temperature of the air surrounding it? What changes take place? What does this prove as to the capacity of warm air for water?

Cold air? What is this process called? What examples of condensation have you seen?

(*b*) *How to find the dew point.* Pour the ice and salt mixture from the tin cup. Wipe the outside until it is thoroughly dry. Half fill the tin cup with cold water. Add chopped ice, a few pieces at a time, stirring constantly with the bulb of a Fahrenheit thermometer. Watch the outside of the cup carefully. When mist begins to form, making the bright tin dim, read the thermometer. This temperature is called the *dew point.* It is the temperature at which condensation begins. This temperature varies greatly on different days and at different places.

What is the dew point of the air in your classroom? Find the dew point of the air out of doors. Is it higher or lower? Can you tell why? What is the relative humidity of air at the dew point? Explain how dew forms.

Problem 2 — Why it rains

Home Problem. — Watch a kettle of boiling water. What makes this water change to steam? Is steam visible? What is the white cloud above the spout of the kettle? How is this white cloud formed? What is it composed of? Hold a dinner plate in this cloud for a few moments. Examine it. Where do the drops of water come from? How are they formed? How are clouds in the sky formed? What are they composed of? Why do clouds float in the air? How do they disappear? How are raindrops formed?

Class Problem. — The kettle of boiling water showed you a few interesting changes that take place when it rains, but not the real cause of rain. *The following experiment will show you this.* Take a large clean Erlenmeyer flask. See that it is perfectly dry both inside and out. Now take

a two-hole rubber stopper to fit the mouth of the flask. Bend a piece of glass tubing at right angles. Push one end of it through one hole in the rubber stopper, so that it will nearly reach the bottom of the flask. Press the stopper into the mouth of the flask. Hold the flask outside the window for a minute to cool it. Now blow through the end of the glass tubing until a fine mist shows on the inside of the flask.

This experiment shows why it rains

Remove the stopper and tubing and quickly close the mouth of the flask with a stopper, which has no hole. Force the stopper in tightly. Now heat the flask by rotating it in a gas flame. Take care not to crack the glass. What becomes of the fine mist on the inside of the flask? Can you see it now? Cool the flask again by holding it outside the window. What happens? Where does this water come from? What makes it condense on the inside of the flask? Heat the flask again. Watch the water disappear. *Which can hold more invisible water vapor, cold air or warm air?* If the air is full of this invisible water vapor and becomes cooler, what happens? If the relative humidity of the air is 75% at 60° F., will it be greater or less if the air is heated to 80° F.? If it is cooled to 40° F.?

PROJECT VII

A STUDY OF WEATHER MAPS

The United States Weather Bureau maintains observation stations all over the country. Daily reports of temperature, wind direction, pressure, and weather conditions are telegraphed daily from these stations. From these reports, daily weather maps are prepared. Storm warnings are sent to ports from which ships sail. Warnings of floods are sent to threatened cities, and frost predictions to farmers. By these means, many lives and millions of dollars' worth of property are saved annually. Arrange to have a weather map sent to your school daily, from your local Weather Bureau. Post these in a conspicuous place and consult them frequently.

Problems — 1. How to read a weather map.
2. How storms travel.

Problem 1 — How to read a weather map

Home Problem. — Study the weather map on page 132. How were the observations for this map taken? What do the different circles indicate? What are the dotted lines? What are the numbers at the ends of these lines? What are the heavy black lines? What are the numbers at the ends of these lines? How is the position of a black line determined? What are the arrows? How can you tell the wind directions from them? Locate your own city on this map. What temperature is given for this locality? What is the pressure? Wind direction? Condition of the weather?

Examine the area marked "LOW." What is the condition of the weather in this area? What is the pressure

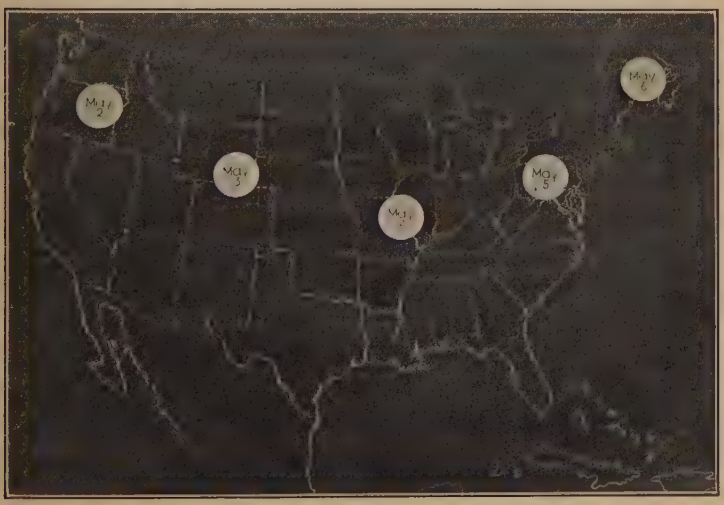
U.S. Department of Agriculture, Weather Bureau
Charles F. Marvin, Chief
DAILY WEATHER MAP
HIGH
LOW
LOW
EXPLANATORY NOTES.
Observations taken at 8 a. m., 75th meridian time.
Air pressure reduced to sea level.
Isobars (continuous lines) pass through points of equal air pressure.
Isotherms (dotted lines) pass through points of equal temperature, drawn for every 10°.
Symbols indicate state of weather: ○ clear; ◑ partly cloudy; ● cloudy; (R) rain; (S) snow; (M) report missing.
Arrows fly with the wind.
Shaded area shows precipitation of 0.01 inch or more during last 24 hours.
Wind velocities of less than 10 miles an hour, and amounts of precipitation of less than 0.01 inch, are not published hereon.
Statute Miles

at the center of the area? How does the pressure change as you move away from the center? Why is this called "LOW"? Notice the directions of the winds about this area. Is the general direction of the wind toward the center of the "LOW" or away from it? Copy this area of low pressure in your notebook.

Examine an area marked "HIGH." What is the condition of the weather in this area? What is the pressure at the center of the area? How does the pressure change as you move away from the center? Why is this called a "HIGH"? Notice the directions of the winds about this area. Is the general direction of the wind toward the center of the "HIGH" or away from it? Copy this area of high pressure in your notebook.

Problem 2 — How storms travel

Class Problem. — Cut out circles of white paper two inches in diameter. Examine the weather map each day.



Many storms travel across the country like this

Wait until a "LOW" appears somewhere in the western part of the country. On a large wall map of the United States pin a circle of white paper to show the location of this "LOW." Examine the weather map on the following day. Locate the same "LOW." Pin a second circle of white paper on the wall map to show its position. Proceed in this way until the "LOW" has traveled all the way across the United States.

In what general direction did this storm travel? About how many miles did it travel the first day? The second day? How many days did it take for this storm to cross the United States? Did this storm pass over your city? What changes did you observe in the direction of the wind, in the pressure, and in the condition of the weather as the "LOW" approached? As it passed away?

PROJECT VIII

HOW TO FORETELL WEATHER

Problem 1 — Weather observations and what they mean

Class Problem. — In Project IV we suggested that you keep a daily record of weather observations on the blackboard. *Examine this record.* On what days did you have fair weather? Stormy weather? How did the temperature change before each storm? Did the barometer rise or fall? How did the wind change? How did the temperature change after each storm? Did the barometer rise or fall? How did the wind change? What does a falling barometer usually indicate? A rising barometer? What kind of weather do easterly winds usually bring? Westerly winds? Explain how storms can come from the west when the winds are easterly.

What kinds of weather would you expect under the following conditions :

(*a*) A gradual, steady rise of the barometer with a southwest wind?

(*b*) A rapid rise of the barometer with a northwest wind?

(*c*) A gradual, steady fall of the barometer with a southeast wind?

(*d*) A sudden fall of the barometer with a northeast wind?

FACTS EVERY ONE SHOULD KNOW ABOUT WEATHER

Invention of the Barometer. — From earliest times men have entertained peculiar beliefs and superstitions concerning weather. The seemingly mysterious changes that brought clear sunny skies, tempests, thunder showers, and devastating hurricanes were attributed to the influence of the stars and planets, or to the will of the gods. It was not until the seventeenth century that the first great discovery, destined to change these old superstitions, was made. A great Italian scientist, Galileo, discovered that a lift pump would raise water only about thirty-two feet. Believing that air pressure had something to do with this, he urged his pupil, Torricelli, to work out the problem. Torricelli took a glass tube about three feet long, and closed one end. He filled this with mercury and inverted the open end into an open cup of mercury, just as you were told to do on page 112. The mercury column in the glass tube suddenly dropped until the top was about thirty inches above the surface of the mercury in the cup. Torricelli reasoned that this column of mercury was balanced by a column of air of equal diameter extending as high as the atmosphere goes. In this way the first barometer, the most valuable of all weather instruments, was invented.

Variable Weight of the Atmosphere. — Men soon discovered that the height of this column of mercury varied. This is due to the fact that the weight of the air changes frequently. At one time the air weighs more and pushes the mercury column up higher in the glass tube. At another time the air weighs less and lets the mercury column drop a little. There are two important causes for these changes; in the first place different temperatures, and

secondly the amount of water vapor present in air. You have already discovered that cold air is heavier than warm air. The greater the amount of water vapor present in air, the lighter it becomes. Therefore, dry air is heavier than moist air. Elevation also affects the height of the mercury column of a barometer; for the higher you go, the lighter air becomes. For this reason aviators and balloonists use barometers to show them how high they are. The principal use of the barometer is to tell when a storm is coming. At the approach of a storm the mercury column falls steadily because the air becomes lighter. All ships carry barometers. Captains watch these closely to determine what the weather conditions are going to be.

Winds. — Winds are caused by unequal heating of the air. Warm air takes up more space than cold air. Heat a flask filled with air and some of the air is forced out. This explains why a flask filled with warm air weighs less than a flask filled with cold air. Put two lamp chimneys on a box and set a burning candle under one of them. The air in the chimney heated by this candle expands, becomes lighter, and is pushed up by the cold heavier air flowing down through the other chimney. Winds start in a similar way. Where any region receives more heat from the sun than surrounding regions, the air over this region expands and rises, being forced up by the colder, heavier air rushing in from the surrounding regions.

The general direction of winds is toward the areas that are called "LOW" on the weather map. "Low" means that the air over these areas is lighter and the barometer reading is low. Wind direction is named after the direction from which the wind comes. A north wind comes from the north and a south wind from the south. Winds blow at different velocities. A light breeze at ten miles per hour

will make leaves flutter on the trees. A strong wind that blows off hats moves about thirty miles per hour. When winds move at the rate of sixty miles per hour trees are uprooted and buildings blown down. Winds influence us in many ways. They keep us cool on hot summer days. They help to dry wet clothes on the line, or muddy streets after a rain. They bring moisture to dry gardens and thirsty plants. They furnish power by turning windmills and driving sailing vessels over the water. Sometimes they blow with such violence that cities are destroyed, ships are wrecked, and many lives are lost.

Moisture. — Water passes into the air from the ground, from the leaves of plants, and from water surfaces such as oceans, lakes, and rivers, by evaporation, changing from a visible liquid to an invisible gas or vapor. Heat, winds, and dry air help evaporation. Cold, still air, and moist air hinder it. Wet clothes dry faster in the sun or back of the kitchen range. They also dry faster when the wind is blowing. On days when air is moist it is difficult to dry clothes. The air contains so much moisture that it is unable to absorb any more.

Evaporating liquids take away large quantities of heat from surrounding objects, making them colder. The more rapid the evaporation the faster heat is taken away and the colder surrounding objects become. Blow on the back of your hand. The warm air from your lungs feels cold, because wind helps the perspiration to evaporate faster and heat is taken away from your hand faster. The evaporation of perspiration is of great importance, for it helps to keep the temperature of the body normal, that is, about 99 degrees (98.6) Fahrenheit. When we run or work hard we perspire freely. Evaporation cools us off and prevents our bodies from overheating. During dog days in summer,

the relative humidity is often very high. It may be as high as 90 per cent or more, and then we feel hot, sticky, and uncomfortable. The air is so full of moisture that scarcely any of the perspiration evaporates to make us cool. In winter, the heated air of our homes is very dry, the relative humidity may be as low as 30 per cent, and rapid evaporation chills the body. In order to feel comfortable we must maintain high temperatures, and our fuel bills are increased considerably. Very low temperatures are produced by *rapid* evaporation. You saw how quickly water may be frozen by the evaporation of ether. Ammonia gas, reduced to a liquid by pressure, is used in a similar way by " cold storage " plants, and by makers of " artificial ice."

Humidity. — Moisture in the air is often spoken of as humidity. " Relative humidity " is an expression you often hear. This, as you have learned, is usually expressed in percentages. Perhaps you noticed that the drier the air, the greater was the difference between the readings of the dry and wet bulb thermometers. When the relative humidity of the air is 100% these readings are the same, for no evaporation takes place from the wet bulb to cool it. When the relative humidity is low, the wet bulb reading is much lower than the dry bulb reading, for rapid evaporation takes heat away from the wet bulb. The relative humidity of the air in different parts of the country is usually given in the daily newspapers. Of course it varies from day to day. It increases at the approach of a storm and decreases as the storm passes away.

Condensation is just the opposite of evaporation. It is the process by which the invisible water vapor of the air changes back to a visible liquid or solid. Condensation forms clouds, fog, dew, rain, hail, frost, and snow. You have

seen the drops of water that collect on the outside of a pitcher of ice water in summer. Cold water pipes frequently "sweat." When you dropped pieces of ice into a bright tin cup containing water, tiny drops of water soon collected on the outside. These come from the air around the cup, changing from an invisible vapor to visible liquid drops. The air around the cup was first cooled by the ice water, and cold air cannot hold as much water vapor as warm air.

In the experiment where you breathed into a flask filled with cold air, you noticed that some of the moisture from your breath collected in tiny drops on the inside of the flask. When you warmed the air in this flask these tiny drops soon disappeared. They changed to an invisible vapor which was taken up by the air. When you cooled the air in the flask a second time, this invisible vapor changed back to tiny drops of water. This experiment showed you that warm air can hold more moisture than cold air. It also explains why drops of water collected on the outside of the tin cup. The different amounts of water vapor that a cubic foot of air can hold at different temperatures are shown in the following table. The weights are given in grains. One pound of sixteen ounces is equal to 7008 grains.

Temperature (Degrees Fahrenheit)	Amount of Water Vapor (Grains per cubic foot)
0	0.54
20	1.30
40	2.86
60	5.76
80	10.95
100	19.79

For every increase of twenty degrees in temperature, the ability of air to hold water vapor is about doubled. A

cubic foot of air at 80 degrees can hold 10.95 grains of water vapor. At 60 degrees it can hold only 5.76 grains. Therefore when a cubic foot of saturated air cools from 80 degrees to 60 degrees, 5.19 grains of water vapor must come out and condense as visible drops.

Clouds. — Clouds are composed of millions of tiny drops of water, so small that they float in the air. It takes over 4000 drops, placed side by side, to stretch across an inch. Clouds are formed when warm air containing water vapor rises. The higher the air rises, the colder it becomes. The colder air becomes, the less water vapor it can hold, and some of it condenses in tiny drops. Clouds are of so many sizes, colors, and shapes that they offer a most interesting study. Perhaps you have noticed on bright sunny days, delicate white wisps, resembling feathers or ribbons. These are called cirrus clouds. They are at a great height, about five miles, and consist of tiny particles of ice. No rain comes from them. When you watch one of these clouds sometimes it melts away and disappears. The tiny particles of ice evaporate and change back to invisible water vapor. This is a sign of fair weather.

During the warm part of the day, especially in summer, you may have noticed clouds that look like great balls of fluffy white cotton. These are called cumulus clouds. No rain falls from them, but they frequently appear before a storm or a thundershower. At times the sky is overcast with a low, flat cloud resembling a gray sheet. This is called a stratus cloud. Dense black clouds, about one mile high, from which rain or snow is falling, are called nimbus clouds. Many other names are given to clouds of different shapes, sizes, and elevations. They change continually from one kind to another. Have you ever traveled through a thick fog, when you could see only a few feet ahead, even

in daylight? Fog is a cloud resting on the ground. It forms when a thick layer of moist air cools suddenly, and is unable to hold all the water vapor it contains. Fogs frequently form in valleys, and over bodies of water, because the air is colder here. They are common in summer during the night and early morning. The sun drives them away by changing the tiny drops of water into an invisible vapor.

You may have noticed drops of dew on the grass on a summer's morning sparkling like diamonds in the sunlight. These form during the night. The air loses its heat quickly after the sun sets, and soon reaches a temperature at which it is completely filled or saturated with water vapor. This temperature is called the dew point. A further drop in temperature causes condensation and dew is formed. The dew point varies with the amount of water vapor in the air. For moist air the dew point is high; for dry air it is low.

Drops of rain form when the tiny drops of water in clouds come together and form larger ones that are heavy enough to fall. If drops of rain pass through warm air filled with water vapor, some of this water vapor condenses on them, and they become still larger. At times, when raindrops fall through layers of dry air they evaporate and disappear before reaching the ground. Snow forms when the temperature of the air is below the freezing point. The invisible water vapor condenses into beautiful crystals of ice. Perhaps you have noticed on cold winter mornings the fairylike designs and patterns on the windows. This is frozen water vapor and is called frost.

Changes in Weather. — The changes in our weather from day to day are caused by the continual movement of "LOWS" and "HIGHS." These are formations of great size, more or less circular in shape, from several hundred miles to over two thousand miles in diameter. Some of

them start in the Mississippi Valley, some over the Gulf of Mexico, and others in the Northwest over the states of Washington and Oregon. They travel across the country like tremendous express trains, in an easterly direction, at an average speed of about thirty miles per hour. Most of them cross the United States in about four days, passing out over New England and Nova Scotia.

"Lows" usually bring stormy weather. As these approach the wind begins to blow from the east, the barometer drops a little, cirrus clouds appear, the temperature rises, and the relative humidity increases. As the "LOW" comes nearer, the barometer drops a little more, the wind may change to the southeast, the clouds become thicker, while the temperature and moisture continue to rise. Next comes a period of rain or snow, with the barometer still dropping and finally reaching its lowest point. The center of the "LOW" is now passing over. The wind slackens and may blow from the south or southwest. Suddenly the wind shifts to the west and then to the northwest. The barometer begins to rise, the clouds break up, the air becomes drier, and the temperature drops rapidly. The storm has passed over and a "HIGH" is coming, bringing fair weather. These changes usually take from two to four days in winter and nearly twice as long in summer. Strange as it may seem to you, storms usually come from the west while the wind usually comes from the east or southeast. The changing of the winds depends on whether the "LOW" passes north of you or south of you. If it passes on the north the changes will be as indicated above. If the "LOW" passes on the south, the wind usually shifts from east to northeast, to north, and finally to northwest.

The movement of these formations called "LOWS" and "HIGHS" accounts for the change in weather from day

to day. One of these formations is passing over you at the present moment, bringing fair weather or storms to your locality. Most people just guess at the weather. If they see clouds in the sky they say, "It is going to rain." If the sun is shining they say, "It will be a fair day." To judge weather properly you will need to watch three things — the daily weather map, the barometer, and the shifting of the winds. These will keep you posted as to the daily locations and movements of the "HIGHS" and "LOWS" which travel across the country, one after the other, bringing fair weather and storms.

CHAPTER V

A STUDY OF FIRE

We are not certain just how primitive peoples first discovered fire. Perhaps it was belched forth from the crater of an active volcano. It may have come down from the clouds in a flash of lightning. At any rate, this discovery marked the real beginnings of civilization. Man stopped eating his food raw. He warmed his cave or hut in winter. With fire, he learned how to take metals out of rocks. Metal implements replaced the pointed stick and the stone hatchet. With these, man began to till the soil, to make better clothing, and to build comfortable homes. As his knowledge of fire increased, he learned how to change iron into steel. This discovery has made possible the remarkable progress of modern times. For with steel, man builds giant steamships, powerful locomotives, comfortable automobiles, and the towering buildings of big cities. To-day we burn fuels not only to furnish heat, but also to furnish light and power. From black lumps of coal comes the brilliant light of the "Mazda" and "Welsbach," or the tremendous power of the steam engine. From a dirty looking mixture, called petroleum, comes the kerosene for our lamps, gasoline for automobiles, and crude oil for big power plants. In the following chapter we want you to find out some facts about the common fuels, how to kindle a fire, how the draft works, how to regulate a fire, how fuels burn, some dangers from fire, and how to put out a fire.

PROJECT I

THE COMMON FUELS

Problems — 1. A study of hard coal.
2. A study of soft coal.
3. A study of coke.
4. A study of wood.
5. A study of liquid fuels.

Problem 1 — A study of hard coal

Class Problem. — (*a*) *Examine pieces of hard coal.* How was this coal formed? How can plants change to coal?

Copyright Keystone View Co.

Some of our coal is mined thousands of feet underground. How did it get there?

How is hard coal mined? Where are the mines located? How is coal shipped from these mines to your home? What color is coal? What is the chemical name for this black substance? Strike two pieces of coal together. Do they break easily? How does hard coal burn? For what purposes is it used?

(*b*) *How hard coal is sold.* How is hard coal screened? What are the common market sizes into which it is separated? Compare the relative sizes of pea, nut, stove, egg, and furnace. Find out the present cost per ton for each size. Where are the different sizes used? Arrange your information as follows:

Size	Cost per Ton	Where Used
Pea		
Nut		
Stove		
Egg		
Furnace		

What sizes cost the most? What are the reasons for this? What are the best sizes to use in the kitchen range? In the furnace? In the heater?

Problem 2 — A study of soft coal

Class Problem. — How is this coal formed? How does the formation of soft coal differ from that of hard coal? Have you ever seen a piece of peat? What does it look like? Can peat change to soft coal? Strike two pieces of soft coal together. How does it differ from hard coal? Why is it dirtier to handle? How does soft coal burn? For what purposes is it used? Is it cheaper than hard coal? What is the reason for this?

Problem 3 — A study of coke

Class Problem. — Examine pieces of coke. What is the color? What is the chemical name of this black substance? How is coke made? What are the little holes in coke? How are these holes formed? Which is heavier, a piece of coal or a piece of coke? How does coke burn? Does it burn as long as hard coal? How does it kindle? How do you regulate the dampers when you burn coke? Does coke cost as much as hard coal? As soft coal?

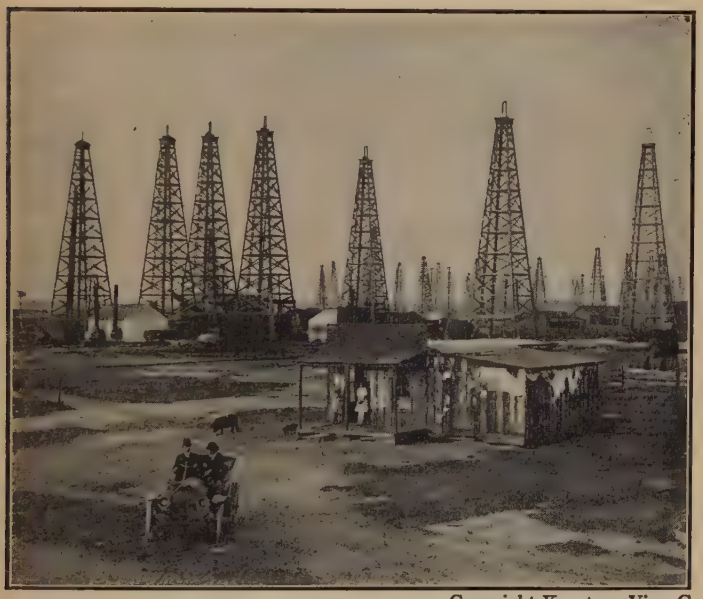
Home Problem. — What kind of coal do you burn at home? What sizes do you use in the kitchen range? In the heater? Why do you use these sizes? How do you know, when you buy coal, that you receive the full weight paid for? What is a public weigher's certificate? What is the value of this? Who signs it? How does it protect you? Do you sift your coal ashes? Why does this cut down your coal bill?

Problem 4 — A study of wood

Home Problem. — What kinds of wood do you use for fuel? Which of these are hard woods? Which are soft woods? How is wood sold? How much is a cord of wood? Is wood cheaper for you to burn than coal? Does it give as much heat as coal? Does it last as long? Why does wood turn black when you burn it? What is this black substance? What is charcoal? Why do you use wood to kindle a fire? Which kindles quicker, soft wood or hard wood? Which gives off more heat? What is left after wood burns? Do you save wood ashes to put on your garden? What is this good for? Why do some woods split easier than others? Why is it difficult to split elm? What are knots in wood? Why does dry wood burn better than green wood?

Problem 5 — A study of liquid fuels

Class Problem. — (*a*) What is petroleum? Where does it come from? How is gasoline made? Kerosene? Paraffin? Vaseline? Put a few drops of kerosene into a tablespoon. Try to ignite it with a burning match. Can



Copyright Keystone View Co.

Oil wells are drilled to great depths by means of derricks like these

you do it? Hold the spoon an inch above the flame of a Bunsen burner. Watch the kerosene start to burn. Why do some people use kerosene to kindle a fire? Hold a white plate in the burning kerosene. What is this black substance? What does this show about the composition of kerosene? For what purposes is kerosene used? What is the cost per gallon? Do you use an oil heater at home? What are some of its good points? Bad points?

(*b*) *Where does alcohol come from?* What is grain alcohol? Wood alcohol? Denatured alcohol? Put a few drops of alcohol into a spoon. Ignite it with a match. What color are the flames? Take a dry, cold, glass jar. Invert it and hold it over the burning alcohol. Watch the sides of the jar. Where does this water come from? What is water composed of? What does this show you about the composition of alcohol? What is left after wood burns? After alcohol burns? How do you account for this? What are some of the advantages of alcohol as a fuel? What are some of the disadvantages?

PROJECT II

HOW TO KINDLE A FIRE

Problems — 1. Why some substances kindle quicker than others.
2. How a match starts to burn.
3. Why we split kindling wood.
4. How to start a fire in the kitchen stove.

Problem 1 — Why some substances kindle quicker than others

Class Problem. — Take the tin cover of a baking-powder can. Fill a glass beaker with boiling water. Float the tin cover on the surface of the water. Cut off a piece of yellow phosphorus, the size of a pea. Always cut phosphorus under water. *Don't touch it with the hands.* Dry the piece of phosphorus with blotting paper, and then drop it into the tin cover.

Drop the phosphorus into the tin cover and see what happens

What kindles the phosphorus? Where does this heat come from? When the phosphorus burns out, scrape the inside of the cover with a knife until it is clean. Refill the glass beaker with boiling water. Again float the tin cover on the surface of the water, and put half a teaspoonful of powdered sulphur into it. Does the sulphur burn? How do you account

for this? With forceps, hold the tin cover over the flame of a Bunsen burner. What kindles the sulphur? Where does this heat come from? Which is hotter, the boiling water or the Bunsen flame? Which has the higher kindling temperature, phosphorus or sulphur? Gasoline or kerosene? Wood or asbestos? Celluloid or rubber?

Problem 2 — How a match starts to burn

Home Problem. — Examine a common "strike anywhere" match. What chemicals are used in the head of this match? Why are these chemicals used? Scratch the head of this match on a piece of rubber. Does it start to burn? Scratch it on a rough surface. What part of the match kindles first? What kindles next? What part kindles last? Why is phosphorus used in the head of a match? Why are the wooden sticks dipped into melted paraffin? Compare the kindling temperatures of phosphorus, paraffin, and wood. What are safety matches? Why is it necessary to scratch them on the box? Where do you keep your matches at home? Can small children reach them? Can rats or mice get at them?

Problem 3 — Why we split kindling wood

Home Problem. — When we want to start a fire we use small pieces of wood first. When these are partly burned we put on larger pieces. *Why do we do this?* Hold a burning match just under an old broom handle. Does it start to burn? With a sharp knife cut off a thin shaving of wood from the broom handle. Hold a burning match just under the shaving. What happens?

Why does a wood shaving kindle quicker than a large piece of wood? To answer this question, hold the point of a pin in the flame of a burning match, until it becomes

Kindling a fire with bow and drill. This boy's record is 50 seconds

red hot. Now try to heat the point of a large nail red hot with a burning match. Can a burning match heat a large object as hot as it can a small object? Why does paper kindle quicker than wood? Don't say the kindling temperature is lower. Why does a small piece of coal kindle quicker than a large piece?

Problem 4 — How to start a fire in the kitchen stove

Home Problem. — Kindle a fire in the coal range at home. Use only paper, wood, and coal. Never use kerosene for this purpose. Where do you put the paper? Why do you crumple it up? Why do you put small pieces of wood on next? How do you arrange these pieces of wood? Why do you lay larger pieces of wood on top? Why do you light the paper first? What kindles the small pieces of wood? The larger pieces? When do you put on the coal? Why? Why not put the coal on the burning paper? Why does the fire go out if you use a small piece of paper? If you do not put on enough wood?

PROJECT III

THE DRAFT AND HOW IT WORKS

Problems — 1. How heat affects air.
2. Is cold air heavier than warm air?
3. What causes a draft?
4. How the dampers in the kitchen stove work.

Problem 1 —How heat affects air

Review Problem 1, page 115.

Problem 2 —Is cold air heavier than warm air?

Review Problem 2, page 116.

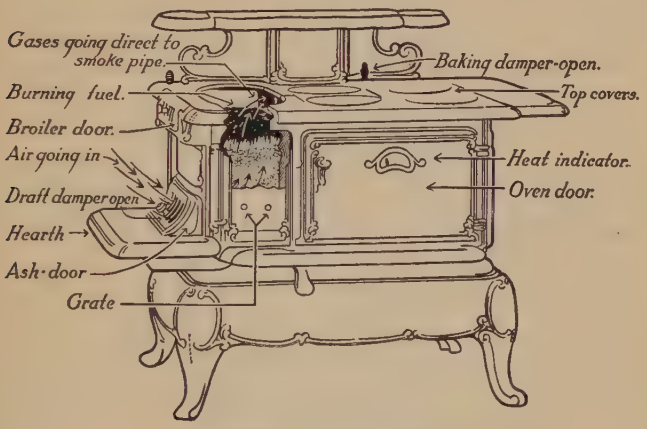
Problem 3 — What causes a draft?

Review Problem 3, page 117.

Problem 4 — How the dampers in the kitchen stove work

Home Problem. — Examine your kitchen stove at home. Locate the different dampers. Tell how they work. Remove the top covers and examine the interior of the stove. *Adjust the dampers for kindling a fire.* Hold a smoking stick in front of the open damper in the ash door. Watch the smoke. Take off one of the front covers. Hold the smoking stick just over the burning fuel. Watch the smoke. How does air go from the ash door damper to the smoke pipe? *Adjust the dampers for checking a fire.* Why do you close the ash door damper? The direct draft damper? Do you close the check damper tight? Why not? *Adjust the dampers for baking.* Trace the circulation of air with a smoking stick from the ash door damper to the smoke pipe. You can do this by removing first one cover, and

then the next, and watching where the smoke goes. Open the oven door. Do you find a small square plate? Remove this and hold the smoking stick in the opening. On how many sides is the oven heated? What keeps



The drafts are set for kindling a fire

the heat from going directly up the chimney from the fire? *Take off the top covers and examine the flues.* Do you find any soot or ashes? Does this make the oven bake better? Clean out the top and end flues. Now remove the soot and ashes from the flues under the oven. How do you do this? Why will the oven bake better now?

(NOTE. — If you don't find a "clean out" plate in the bottom of the oven, look for a small "clean out" door on the outside of the stove, which will give access to the space under the oven.)

PROJECT IV

HOW TO REGULATE A FIRE

Problems — 1. A study of oxygen.
2. A study of carbon dioxide.
3. How to make a fire burn fast.
4. How to check a fire.

Problem 1 — A study of oxygen

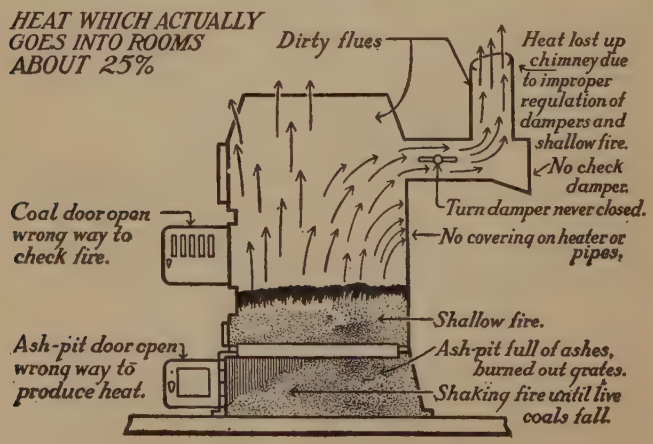
Review Problem 1, page 4.

Problem 2 — A study of carbon dioxide

Review Problem 3, page 7.

Problem 3 — How to make a fire burn fast

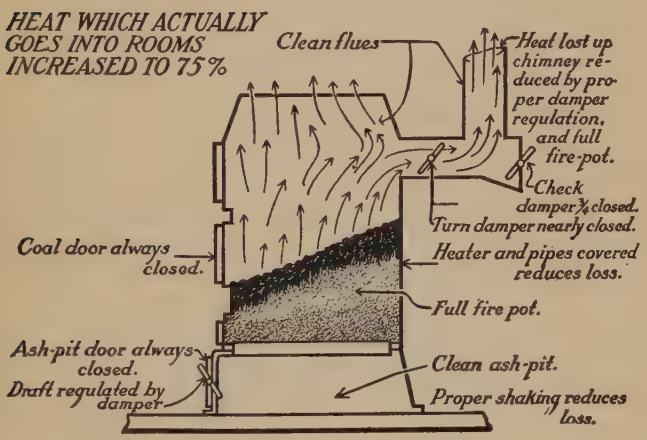
Class Problem. — Set four short paraffin candles close together. Lay two rulers parallel, and on opposite sides of the candles. Light the candles. Now take a tall lamp


HEAT WHICH ACTUALLY GOES INTO ROOMS ABOUT 25%
Dirty flues
Heat lost up chimney due to improper regulation of dampers and shallow fire.
No check damper.
Turn damper never closed.
No covering on heater or pipes,
Coal door open wrong way to check fire.
Shallow fire.
Ash-pit door open wrong way to produce heat.
Ash-pit full of ashes, burned out grates.
Shaking fire until live coals fall.

The wrong way to regulate a fire

chimney. Bring this down over the burning candles and let the base rest on the two rulers.

How do the candles burn? Why do they burn so brightly? Hold a smoking stick near the base of the chimney. Where does the smoke go? What carries this smoke up the chimney? Remove the two rulers, and let the base of the lamp chimney rest on the table. What


HEAT WHICH ACTUALLY GOES INTO ROOMS INCREASED TO 75%
Clean flues
Heat lost up chimney reduced by proper damper regulation, and full fire-pot.
Check damper ¾ closed.
Turn damper nearly closed.
Coal door always closed.
Heater and pipes covered reduces loss.
Full fire pot.
Ash-pit door always closed.
Draft regulated by damper
Clean ash-pit.
Proper shaking reduces loss.

The right way to regulate a fire

happens? Explain. Why does a bonfire burn faster on a windy day? Why does a smoldering fire burst into flame when you blow on it? When you fan it?

Home Problem. — How do you make a fire burn fast in the kitchen stove? How do you adjust the dampers? Why do you open the ash door damper? The direct draft damper? The check damper? How do you make a fire burn fast in the furnace or heater? Write an account of what you do and the reason for each operation.

Problem 4 — How to check a fire

Home Problem. — How do you check a fire for the night in your kitchen stove? Why do you close the ash door damper? Why do you partly close the check damper? The turn damper? Why do you put cinders on the fire?

Class Problem. — (*a*) Lower a burning candle into a quart milk bottle with a piece of wire. Cover the top of the bottle. Watch the flame of the candle. Why does it go out? Why does it burn for a few seconds before it goes out?

(*b*) *Does the candle flame go out because the oxygen is used up?* Take a pint bottle with a wide mouth. Fill with water and invert into a basin of water. Make some oxygen, and let it bubble into the bottle through a rubber tube until one-fifth of the water in the bottle is forced out. Now make some carbon dioxide. Let this bubble into the bottle in the same way until all the water in the bottle is forced out. The bottle now contains a mixture of two gases: about one-fifth is oxygen, and about four-fifths is carbon dioxide. Hold the palm of one hand over the mouth of the bottle and shake, to mix the gases. Now thrust a blazing splint into the bottle. Why does it go out? Air contains about one-fifth oxygen and four-fifths nitrogen. Therefore the bottle contains as much oxygen as if it were filled with air. Does the splint burn in air? Then why doesn't it burn in the bottle? Did the burning candle use up all the oxygen in the milk bottle? Why did the flame of the candle go out? Why does the fire in the kitchen stove go out when you close the check damper tight?

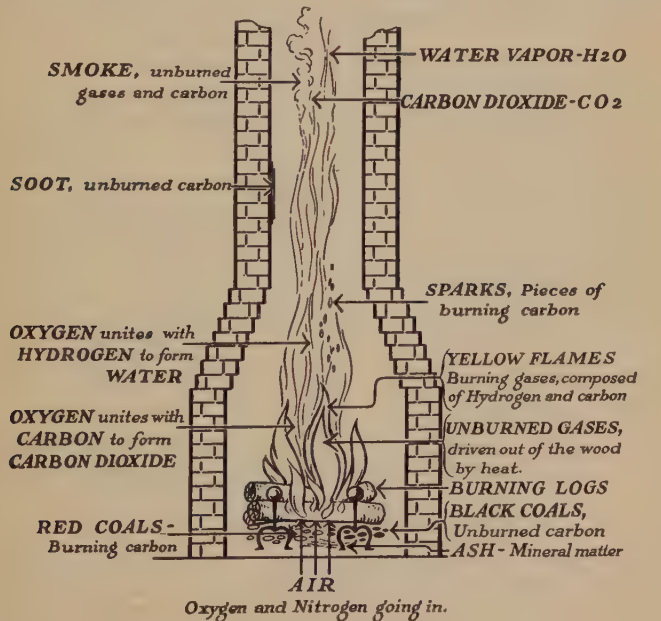
PROJECT V

HOW FUELS BURN

Problems — 1. How wood burns.
2. What becomes of wood when it burns?
3. Do fuels weigh more after they burn?
4. What is smoke?
5. How coal burns.

Problem 1 — How wood burns

Home Problem. — Watch wood burn in the fireplace or the kitchen stove. What are the yellow flames? Why do


SMOKE, unburned gases and carbon
SOOT, unburned carbon
OXYGEN unites with HYDROGEN to form WATER
OXYGEN unites with CARBON to form CARBON DIOXIDE
RED COALS - Burning carbon
AIR
Oxygen and Nitrogen going in.
WATER VAPOR-H2O
CARBON DIOXIDE-CO2
SPARKS, Pieces of burning carbon
YELLOW FLAMES Burning gases, composed of Hydrogen and carbon
UNBURNED GASES, driven out of the wood by heat.
BURNING LOGS
BLACK COALS, Unburned carbon
ASH - Mineral matter

How wood burns and what becomes of it

these flames become smaller after the wood burns a short time? What makes the wood snap? What are sparks?

Why do sparks fly when wood burns? What are the blue flames? What are the red coals? Why do these burn without yellow flames? What are the black coals composed of? What does this show about the composition of wood? What is left after wood burns? Examine some of this substance. Describe it. Why didn't it burn? Where do trees get this substance?

Class Problem. — *What are the yellow flames?* Half fill a test tube with fine wood shavings or sawdust. Bend a short piece of tubing at an angle. Push one end through the hole in a cork stopper. Push the stopper into the mouth of the test tube. Heat the test tube evenly and slowly over a gas flame. Hold a burning match just over the open end of the glass tubing. What happens? What is the substance that forms? Where does it come from? What are the yellow flames when wood burns? When coal burns? When paper burns? When dry grass burns? Why does charcoal burn without yellow flames?

Problem 2 — What becomes of wood when it burns?

Home Problem. — Set a clean, dry drinking glass outside the window, until it becomes cold. Light a match. Wait until the wood burns with a bright flame. Now hold the glass upside down, and thrust the burning match into it. What collects on the inside of the glass? How are these drops of water formed? What is water composed of? Where does the hydrogen come from? The oxygen? What happens to these elements when wood burns?

Class Problem. — Repeat Problem 7, page 31.

Problem 3 — Do fuels weigh more after they burn?

Class Problem. — Take the tin covers of two baking-powder cans. Punch three small holes in the side of each

cover. Slip the end of a piece of fine wire through each hole and fasten it. Twist the wires together at the top, so that each cover hangs evenly. Now hang a sensitive hand balance from a ring stand support. Suspend a tin cover from either arm of the balance. Put a heaping teaspoonful of *magnesium powder* into one of the tin covers. Sprinkle fine sand into the other cover until the two covers

Take the flame away when the magnesium starts to burn

balance. How do the weights of the sand and magnesium powder compare? Now hold a gas flame under the tin cover containing the magnesium powder. Heat the bottom of the cover until the magnesium starts to burn.

How does it burn? Remove the gas flame. Watch the tin covers for three or four minutes. Why does the tin cover that contains sand rise? Why does the tin cover that contains magnesium go down? Which is heavier, the sand or the burnt magnesium? Examine the substance left in the cover. Describe it. What happens when mag-

nesium burns? What does it unite with? Where does this gas come from? The white substance that is left after magnesium burns is called *magnesium oxide*. Why is it called this? Why does the magnesium oxide weigh more than the magnesium did? When a hod of coal burns, where do the products go? Will the stuff that goes up the chimney weigh more or less than the coal?

Problem 4 — What is smoke?

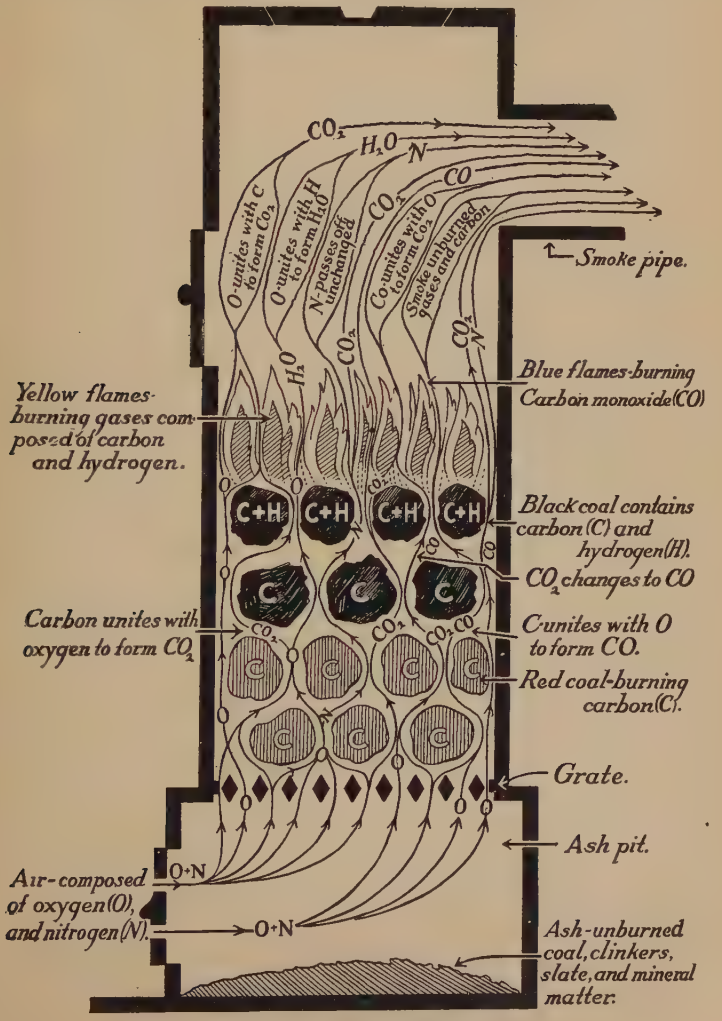
Home Problem. — (*a*) Take a stick of soft, dry wood, such as pine or spruce, about twelve inches long and half an inch wide. Hold one end in a fire until it burns vigorously, with a large yellow flame. With a forceful breath, blow out the flames. Watch the smoke. Light a match. Hold the match flame in the smoke. Repeat several times. What happens? What are the yellow flames when wood burns? What drives these gases out of the wood? Why are the flames extinguished when you blow on them? Why does the stick give off smoke? Explain why this smoke burns when you hold a burning match in it.

(*b*) Relight the stick of wood. Let it start to burn with bright yellow flames. Thrust the blazing end of the stick into a quart milk bottle or jar. What happens? Why is the flame extinguished? Why does the wood continue to give off smoke?

Why does a fire in the kitchen stove smoke, when you add fresh fuel? When you close the dampers too tightly? When the stove is filled with soot or ashes? When you try to burn damp or green wood? Does burning charcoal give off smoke? Why does soft coal smoke more than hard coal? Where does the black soot in flues and chimneys come from? Why do chimneys catch fire? Why does smoke waste fuel? How can you avoid smoke?

Problem 5 — How coal burns

Home Problem. — Watch the burning coal in your kitchen stove or heater. What are the yellow flames? Why do



How coal burns and what becomes of it

these flames disappear soon after the coal starts to burn? What are the red coals? Which burns longer in coal, the gas or the carbon? Which gives off more heat? What is the black substance in coal called? What becomes of this when coal burns? Coal also contains hydrogen. What becomes of this when coal burns? What goes up the chimney from a coal fire?

Notice the blue flames that are given off when coal burns. These blue flames are also given off from burning coke, wood, illuminating gas, and gasoline. They are produced by the burning of a deadly poisonous, colorless gas, called *carbon monoxide.* This gas is given off when there is not enough oxygen to burn the fuel. Why are the blue flames larger when you put fresh coal on the fire? When you close the check damper or turn damper? What color are the flames of your gas range? Why does illuminating gas kill people? Why do some people die when they close the dampers of their stoves too tightly at night? Why is it dangerous to breathe the air in a closed garage when an automobile motor is running? Why are leaking hot air furnaces dangerous? Carbon monoxide is invisible. It has almost no odor. Why is it more dangerous on this account?

PROJECT VI

SOME DANGERS FROM FIRES

Problems — 1. How a fire starts itself.
2. Why gasoline is dangerous.
3. How illuminating gas explodes.
4. How dust explodes.
5. How to protect our homes from fire.

Problem 1 — How a fire starts itself

Disastrous fires frequently start themselves in piles of rubbish, damp hay, damp straw, oil waste, and rags saturated with grease, paint, or turpentine. Perhaps you have seen piles of horse manure steam and burn when they are turned over in the spring. The following experiment will show you how fires can start themselves.

Class Problem. — Put two teaspoonfuls of carbon disulphide into a small beaker. *Keep this away from a flame.* Drop a piece of yellow phosphorus, the size of a pea, into the beaker. Let the phosphorus dissolve in the carbon disulphide. Lay a sheet of paper on an iron ring or a ring stand. Carefully pour some of the liquid from the beaker over the paper. Set a plate under it to catch the drip. *Take care not to get any of this liquid on the hands or clothing.* Now watch the sheet of paper for a few minutes. *What happens?* Did the fire start itself? Rags saturated with grease, paint, oil, or turpentine sometimes act in a similar way, though much more slowly. *Do not* let piles of rubbish accumulate in your home. *Burn all greasy rags, or put them in metal containers.*

Problem 2 — Why gasoline is dangerous

Class Problem. — Take a Karo Corn Sirup can with a friction cover. The quart size works best. With a file make a circular hole about half an inch in diameter in the side of the can and near the top. Set the can on a ring stand support. Place one candle under the can. Place a second candle close beside the can, so that the top of

He knows what is going to happen

the candle is just below the circular hole. Now put four to six drops of good gasoline into the can. Fit the cover and press it down tightly.

Light the candle beside the can. Then light the one under the can, and step back a few feet at once. *What happens?* Why does gasoline explode? Why do you place one candle under the can? What is an explosion? What forces the cover off? What makes the noise? Why is gasoline more dangerous than kerosene? Ether, benzine, and naphtha are also extremely dangerous. What is the reason for this? Do you use any of these substances at home? Where do you keep them?

Problem 3 — How illuminating gas explodes

Many serious accidents have been caused by explosions of illuminating gas. Do you ever hunt for leaking gas with a burning candle or match? The following experiment will show you the danger of this practice.

Class Problem. — Take a tin coffee can, holding about a quart, with a tight-fitting cover. With a file, punch a hole in the center of the cover, the size of a lead pencil. Make a second hole, half an inch in diameter, in the side of the can, and near the bottom. Take a short piece of rubber tubing. Connect one end to a gas jet. Slip the other end of the tubing through the hole in the side of the can. Turn on the gas. Let it flow for about twenty seconds. The can is now filled with illuminating gas. Pull out the rubber tubing, and turn off the gas cock. Hold a burning match just over the hole in the cover. Watch the gas burn for several minutes. Keep away from the can when the flame apparently "goes out."

Stand away from the can and listen

What color is the flame at first? How does it change in color? What goes into the can through the hole in the side? What happens after a few minutes? What causes this explosion? What forces the cover off? What makes the noise? Why doesn't the gas explode when you first light it? What must be mixed with illuminating gas to cause an explosion? Does this mixture contain more illuminating gas or more air? Why do you think so? How can a small gas leak cause a dangerous explosion?

Problem 4 — How dust explodes

Dust seldom explodes in houses. In flour mills, grain elevators, and coal mines it sometimes explodes with great violence, destroying buildings and causing loss of life.

Class Problem. — For this experiment use a five- or ten-pound peanut butter can, with a friction top. Buy an ounce of *lycopodium powder* from a druggist. Lycopodium powder is used because it is very fine. Punch a hole, half

The can is cut away to show how it works

an inch in diameter, in the bottom of the can, and in the center. Set the can on a ring stand. Place a funnel inside the can. Push the stem of the funnel down through the hole in the bottom of the can, so that the funnel stands erect. The stem of the funnel should protrude at least an inch below the bottom of the can. Take a short piece of rubber tubing. Slip one end over the stem of the funnel. Now take a paraffin candle, not over an inch long. Set this on the bottom of the can, inside. Light the candle. Pour a teaspoonful of lycopodium powder into the funnel. Raise the end of the rubber tubing to prevent the powder

from running out. Fit the tin cover on the can and press it down tightly. Put the open end of the rubber tubing in your mouth, and blow with a quick forceful breath. *Don't stand too close to the can.*

What happens? What causes this explosion? What forces the cover off? What makes the noise? Is lycopodium powder an explosive? Put half a teaspoonful on the tin cover. Try to ignite it with a burning match. How do dust explosions take place? Why does fine dust explode more easily than coarse dust?

Problem 5 — How to protect our homes from fire

The loss by fire of human lives and property in the United States every year is appalling. It is a terrible story of suffering, death, and destruction. What precautions have you taken to guard your home from the *"Demon Fire"?*

Home Problem. — Inspect your home and write a neat report. *Be a good home fire warden.*

1. What kinds of matches do you use at home?
2. Do you keep these matches in a metal box?
3. Can your little brothers or sisters reach these matches?
4. Are there piles of rubbish in the basement?
5. What do you do with rags covered with grease, oil, paint, or turpentine?
6. Is the chimney of your house in good repair?
7. Has it been cleaned out recently?
8. Where do you dump hot ashes?
9. Do stove pipes pass through closets or wooden partitions?
10. Where do you throw waste paper?
11. Do you keep or use gasoline, naphtha, or benzine in the house?

12. Do you use kerosene lamps? Do you keep them clean and filled? Do you go to sleep and leave them burning?

13. Are any of your gas fixtures connected with detachable rubber or metal tubes?

14. Do you use a gas jet near a window shade or curtain?

15. Has the electric wiring in your house been carefully inspected?

16. Does any member of your family smoke in bed?

17. Is your garage a safe distance from the house?

18. Does your house need fire escapes?

19. In case of fire at night how would you get out?

20. Have you a fire extinguisher in the house?

21. Where is the nearest fire alarm box?

22. Do you know how to turn in an alarm?

23. What is the telephone number of your fire department?

24. What changes have you made to better protect your home from fire?

PROJECT VII

HOW TO PUT OUT A FIRE

Problems — 1. How water puts out a fire.
2. How a fire extinguisher works.
3. How to put out burning gasoline.

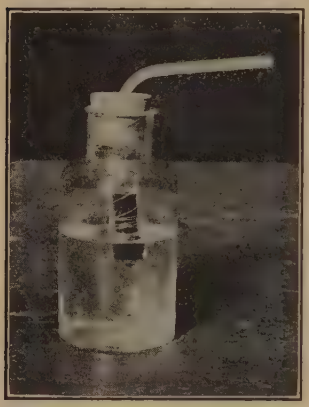
Problem 1 — How water puts out a fire

Home Problem. — Take a sheet of writing paper. Dip it into water two or three times. Hold a burning match under one corner of the wet paper until it starts to burn. Does the paper burn fast? What happens to the water before the paper burns? How does evaporation affect the temperature of surrounding objects? Why is the paper cooled when the water evaporates? Explain why wet paper burns more slowly than dry paper. Why do firemen play streams of water on burning buildings? What happens to some of the water when it strikes the fire? How does this affect the temperature of the burning materials? Why does the fire go out? Will hot water put out a fire? How do you account for this?

Problem 2 — How a fire extinguisher works

Home Problem. — Pour half an inch of vinegar into a common drinking glass. Add an even teaspoonful of baking soda. Describe the action that takes place. What are the bubbles? What are they filled with? Let the foam settle. Light a match, and thrust the flame into the drinking glass. What is the result? Describe the substance formed by the action of vinegar and soda. What is this action called? Could you use this same substance in a fire extinguisher?

Class Problem. — (*a*) Make a small fire extinguisher and operate it. Take a half-pint glass bottle with a wide mouth. Half fill with cold water. Add an even teaspoonful of common baking soda. Shake until the soda dissolves. Bend a piece of glass tubing, four inches long, at right angles. Push one end barely through the hole in a rubber stopper. Take care that it fits tightly. With fine wire fasten a small glass vial to one end of a stiff piece of iron wire. Push the other end of the stiff wire into the bottom of the rubber stopper. With care, pour a teaspoonful of concentrated sulphuric acid into the vial. Lower the vial into the bottle, and force the rubber stopper firmly into the mouth of the bottle. The fire extinguisher is now ready to use.

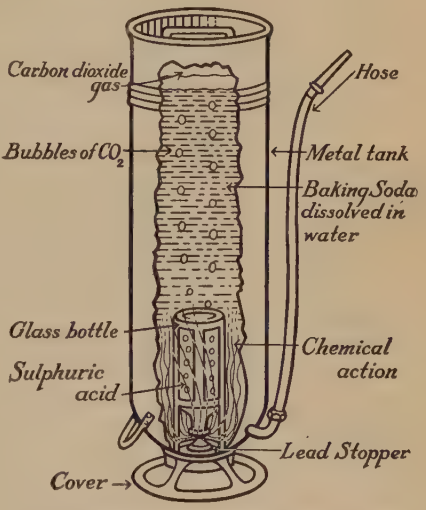


What happens when you invert the bottle?

Set a large dish pan on four bricks or flat stones. Start a small fire in the dish pan with pieces of wood from a chalk box. Take the fire extinguisher with both hands. Place both thumbs on the bottom of the bottle, and the fingers on top of the rubber stopper. Squeeze as hard as you can to keep the stopper from being forced out. Tip the bottle upside down, pointing the nozzle of the glass tubing at the fire. Why is it necessary to invert the bottle? Describe the action that goes on inside. Why are the contents of the bottle driven out with such force? Why is the fire extinguished?

(*b*) *What substance is forced out of a fire extinguisher?* Take a small bottle with a wide mouth and half fill with

water. Add an even teaspoonful of soda and shake. Take a piece of glass tubing, four inches long, and bend at right angles. Push one end through a hole in a two-hole rubber stopper. Over the other end, slip a piece of rubber tubing about two feet long. Through the second hole in the stopper push the stem of a thistle tube, so that it nearly touches the bottom of the glass bottle. Fit the stopper tightly into the mouth of the bottle. Fill a pint jar with water, and invert it into a basin of water. Slip the open end of the rubber tubing under the mouth of the jar. Now pour concentrated sulphuric acid down the thistle tube, a few drops at a time.



A fire extinguisher inverted to show action

Describe the action in the bottle. What takes place in the jar? What are the bubbles? Where do they come from? Why is water forced out of the jar? Slip a piece of cardboard under the mouth of the jar, and set it upright on the table. Thrust a blazing splint of wood into the jar. What happens? Pour an inch of clear lime water into the jar and shake. *What happens?* What gas is formed by the action of soda and sulphuric acid? What color is this gas? How can this gas put out a fire? Why are the contents of a fire extinguisher forced out so violently? Why do you invert a fire extinguisher to start it?

Problem 3 — How to put out burning gasoline

It is difficult to extinguish a gasoline fire. Gasoline floats on water. For this reason water is practically useless to put out such a fire. The best method is to shut off the supply of oxygen.

Class Problem. — (*a*) Take a tin can that holds about a quart. Put one teaspoonful of gasoline into it. Drop a burning match into the can. What happens? Lay a wet cloth over the top of the can. Why does the fire go out? Why do small motor boats sometimes carry pails of sand? If a person's clothing should catch fire, how would you try to put it out?

(*b*) *Put an even teaspoonful of gasoline into an evaporating dish.* Light it carefully with a match. Pour water on the burning gasoline. Does this put out the fire? Why? Pour a little carbon tetrachloride on the burning gasoline. Why does this put out the fire? The heat changes carbon tetrachloride to a gas. This gas spreads over the fire, like a blanket, and shuts off the supply of oxygen.

FACTS EVERY ONE SHOULD KNOW ABOUT FIRE

Fuels. — Of all fuels, coal is the most essential. Perhaps your city has experienced at some time the trials of a coal shortage, when factories shut down, transportation is held up, food supplies run short, and even street lights are shut off at night. Coal is formed from trees and plants which grew many centuries ago in great swamps. As these trees and plants died, they fell down and accumulated in layers of partly decayed vegetable matter. In the course of time, this vegetable matter was buried under thick beds of sand and mud, and slowly changed to coal. Peat is formed in the same way, in swamps, from dead mosses, grasses, and other plants. When properly dried, peat makes an excellent fuel and is used for this purpose to-day, especially in Ireland and Russia.

Most of the hard coal used in the United States comes from Pennsylvania. When taken out of the mines, hard coal is crushed by a machine, and is then screened into different sizes, such as pea, nut, stove, egg, and furnace. Pea and nut are the best sizes to burn in the kitchen range. The stove and egg sizes are used in furnaces and heaters. Hard coal is composed mostly of carbon. It contains only a small quantity of gas. For these reasons, it burns evenly and slowly, with little smoke or yellow flame, and gives an intense heat.

Soft coal contains less carbon than hard coal, and more gas. It is a much dirtier fuel to use. It burns up more quickly, giving off considerable smoke and yellow flame. Soft coal is used mostly for large heating plants and for steam engines. It is also used to make illuminating gas.

Coke is an excellent fuel. It is clean, kindles easily, gives much heat, and burns with a bright glow and almost

no yellow flame. A coke fire, however, goes out easily and needs frequent attention, unless the fire pot is deep.

Wood makes a quick, cheerful fire. In some places, where it is cheap, wood is used almost entirely for fuel. It contains less carbon and gives off more gas than coal. For these reasons it burns with more smoke and more yellow flame. Wood does not give as much heat as coal. It also burns up quickly, making a very unsteady heat.

Kindling Temperature. — Some substances start to burn at a lower temperature than others. They have a lower *kindling temperature*. The kindling temperature of yellow phosphorus is so low that even the heat of the hand will start it burning. The heads of many matches contain phosphorus. When you scratch the head of a match, enough heat is generated by friction to raise this phosphorus to its kindling temperature. The paraffin of a match burns next, for the burning phosphorus generates enough heat to raise this paraffin to its kindling temperature. Finally the burning paraffin generates enough heat to raise the wooden match stick to its kindling temperature.

When you start a fire in the kitchen range, you first lay crumpled paper on the grate, then you put on small sticks of wood, and on top of these you lay larger sticks. A burning match generates enough heat to kindle the paper, the burning paper generates enough heat to kindle the small sticks of wood, and the small sticks of wood generate enough heat to kindle the larger sticks. When the larger sticks of wood begin to burn vigorously, you put on the coal. Enough heat is generated by the larger sticks to kindle the coal. The kindling temperature of wood shavings and big sticks of wood may be the same. Wood shavings kindle quicker than big sticks of wood because they become hot quicker. It is much easier to kindle a fire with pea

coal or nut coal than with the larger sizes, such as stove, egg, or furnace.

Some people frequently have difficulties in kindling a fire. The following simple rules will help them. Clean out the ashes and old fuel. Use plenty of paper. Crumple up the paper. Lay small dry sticks of wood on the paper. Put larger sticks of wood on top. Cross the sticks slightly. Use plenty of wood. Wait until the wood burns brightly before putting on coal. Don't put on too much coal at a time. When the coal starts to burn, punch it down with a poker, and then put on a little more.

Draft. — Have you examined your coal range at home? In the ash door you will find a slide, called the ash door slide. Near the smoke pipe you will find two dampers. One of these slides back and forth. This is called the check damper. The other damper, called the direct draft damper, is usually operated by a little knob that you push forward and back. If you take off the front covers on top of the stove and look inside, you will see how the direct draft damper works. You open it to start a fire. This allows the hot gases from the fire to pass directly up the smoke pipe. When you want to heat the oven for baking, you close this damper. The hot gases must now pass around the oven to reach the smoke pipe. When there is a fire in a stove, the cold air of the room first passes through the ash door slide, and next through the burning fuel. Here the air becomes heated. Some of it is used up, and new gases are formed. Heat makes these gases expand and consequently weigh less than the cold air outside the stove. For this reason the cold heavy air pushes the warm gases up the chimney, causing a draft. The greater the difference between the temperature of the air in the room and the gases in the stove, the stronger will be

the draft. This explains why a fire burns better after the stove and the smoke pipe become hot.

To make a fire burn fast, you open the ash door slide, the check damper, and the direct draft damper. This allows a continual supply of fresh air to pass through the burning fuel. Now air contains a gas, called oxygen, which helps things to burn. Hence, a larger supply of air furnishes more oxygen to make the fire burn fast. There are several ways to check a fire. You can close the ash door slide, and cut down the supply of oxygen. You can close the check damper in the smoke pipe. This stops the circulation of gases in a stove in the same way that a dam stops the flow of water in a stream. Some of the carbon dioxide, formed by the burning fuel, is held back, and checks the fire.

Flame and Oxygen. — When a candle burns in a closed space, such as a bottle, the flame soon goes out. This happens before the oxygen is all used up, and because of the presence of carbon dioxide. In one of your experiments you learned that a candle will not burn in a mixture of oxygen and carbon dioxide which contains as much oxygen as does air. When any fuel containing carbon burns, this carbon unites with oxygen of the air to form carbon dioxide. Unless this gas is allowed to escape it puts out the fire long before the oxygen is used up. Air containing twenty per cent of carbon dioxide will put out a fire. When you check a fire for the night, take care not to close the dampers in the smoke pipe tight. There must be a little draft up the chimney or a deadly poisonous gas, called carbon monoxide, will escape into the rooms of a house, causing severe headaches and even death.

Smoke. — Smoke is a mixture of water vapor, carbon, burned gases, unburned gases, and soot. It is caused by

lack of heat, or lack of oxygen. Let a stick of wood burn for a few minutes and then blow out the flame. The stick smokes. This smoke consists mostly of unburned gases. There is sufficient heat to drive these gases out of the wood, but not enough heat to raise them to the kindling temperature. A lamp smokes when the wick is turned up high. This is due to the fact that the supply of oxygen is too small to burn the kerosene vapor. Adding fresh fuel to a fire in too large quantities causes smoke, because it cools the fire. A poor draft in a stove cuts down the supply of oxygen, and makes it smoke. This may happen when you kindle a fire in a cold stove, when the flues or chimney are filled with soot, or when there is a thick bed of ashes on the grate. Smoke is a waste of fuel and costs money. To avoid smoke, keep the ash pan, flues, smoke pipe, and chimney clean. Shake down the fire occasionally. Feed fresh fuel in small quantities. Don't close the dampers too tight.

It is a pleasant experience to sit before the blazing logs of a fireplace or camp fire at night and watch the tongues of yellow flame shooting upward. The crackling of the wood as it burns, the sharp explosions which send out showers of bright sparks, the white smoke as it slowly rises, and the warm embers of glowing red coals all contribute to the enjoyment. When you put fresh wood on the fire, gases are driven out by the heat, and burn with a yellow flame. At times these gases are formed in the tiny cells of the wood, just under the surface, and cannot escape. They explode, blowing off the surface of the burning wood in showers of bright sparks. Soon all the gases are driven off and the yellow flames die down. Red glowing embers are left, which send off lots of heat. These embers are burning carbon. Soon this carbon disappears. It com-

bines with oxygen of the air and goes off as carbon dioxide. Unless fresh fuel is added the fire soon goes out, leaving a bed of gray ashes, composed of mineral matter, and a few black coals of unburned carbon.

When such fuels as wood or coal burn, a little ash is left. Where does the rest of the fuel go? You have learned that the carbon unites with oxygen to form a gas called carbon dioxide. One pound of carbon unites with *2.67* pounds of oxygen and forms *3.67* pounds of carbon dioxide. The hydrogen in fuels also unites with oxygen and forms water. One pound of hydrogen unites with *eight* pounds of oxygen and forms *nine* pounds of water. Hence the gases that go up the chimney weigh several times as much as the fuel did.

Fire Prevention. — Every home should be equipped with a good fire extinguisher. There are several kinds on the market. One kind, that is especially effective, contains soda, water, and sulphuric acid. A metal cylinder is partly filled with common baking soda dissolved in water. Above this is suspended a glass bottle with a loose-fitting lead stopper, and containing sulphuric acid. To operate, it is necessary to tip this fire extinguisher upside down. The lead stopper drops out of the bottle, letting the acid and soda water mix. Violent chemical action takes place, and large quantities of carbon dioxide are generated. The metal cylinder cannot hold all this gas and some of it is forced out violently through the nozzle on to the fire. Perhaps you have noticed that carbon dioxide is a very heavy gas, being much heavier than air. Because of this, it spreads out over a fire like a blanket and puts the fire out.

Water puts out a fire in a peculiar manner. When it strikes the burning fuel some of the water evaporates.

Evaporation is a cooling process, as you know. The burning fuel is cooled below its kindling temperature, and the fire goes out. Don't throw water on burning gasoline, naphtha, or benzine. These liquids float on water. You can shut off the supply of oxygen by throwing a blanket or sand over a fire of this kind, or you can put it out with a fluid called *carbon tetrachloride*. This fluid evaporates quickly and forms a gas which covers the fire and puts it out by shutting off the air.

Fire takes a terrible toll of life and property in the United States every year. During the year 1920, fifteen thousand persons were burned to death. The property loss amounted to five hundred million dollars. *Think of it!* And this appalling loss of life and property was due mostly to one thing — **carelessness**. *Be your own home fire warden.* Make your home safe from fire. Never throw rags covered with oil, paint, or turpentine in closets or corners. Don't let piles of rubbish accumulate in the basement or attic. Never use gasoline, benzine, or naphtha in the house. Keep your matches in a tin box, out of reach of your younger brothers and sisters. Never hunt for a gas leak with a match, candle, or lamp. Don't play with fire. The "Terrible Demon Fire" may visit your home next. *Watch out for him.*

CHAPTER VI

HOW WE HEAT OUR HOMES

PRIMITIVE man heated his cave or hut in winter by building an open fire on the ground. Some of the smoke escaped through a hole in the roof. At a later date men built fireplaces of stone. These carried off the smoke better than the open fire. Much of the heat, however, went up the chimney and was wasted. In 1742, Benjamin Franklin invented the first stove. It was simply a box with metal sides and an open front. Since this date many improvements have been made. Stoves are still used for heating in the majority of homes. In many houses, however, fires are built in cellar or basement, and heat is carried by air, water, or steam to all the rooms. In the following chapter, we want you to find out some facts about heat and how it travels, hot air heating, hot water heating, steam heating, and heating with illuminating gas. These facts may help you to run your heating system better and at less cost.

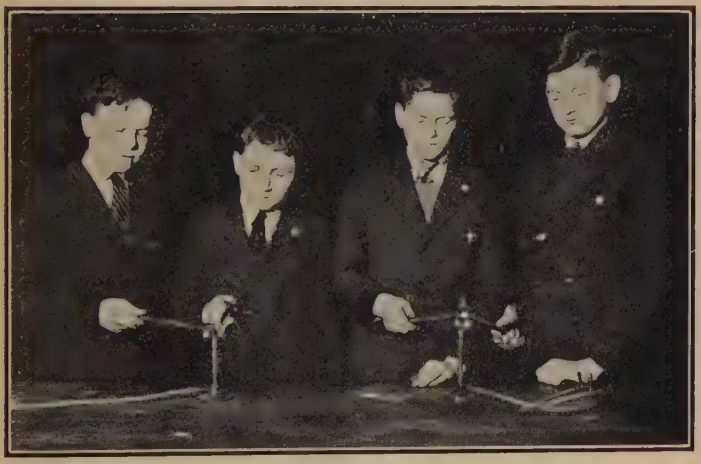
PROJECT I

HOW HEAT TRAVELS

Problems — 1. How heat travels through metals.
2. How my kitchen is warmed.
3. How a fireplace warms a room.
4. How color affects heat changes.

Problem 1 — How heat travels through metals

Class Problem. — Take four metal rods, one-half inch in diameter and twelve inches long; one rod of copper,



Which boy will win?

one of aluminum, one of brass, and one of iron. The assistance of four pupils is needed to perform this experiment. Let each pupil pick out one of the metal rods, and grasp each rod firmly near one end. Light two Bunsen burners. Hold two metal rods over one burner and two over the other. At the command "*Go*" let each pupil bring an end of his

rod into the gas flame, and hold it there. *Who can hold a metal rod for the longest time?* With a watch, time each of the contestants in seconds.

Which rod is dropped first? Second? Third? Fourth? Arrange the results of this contest in a table as follows:

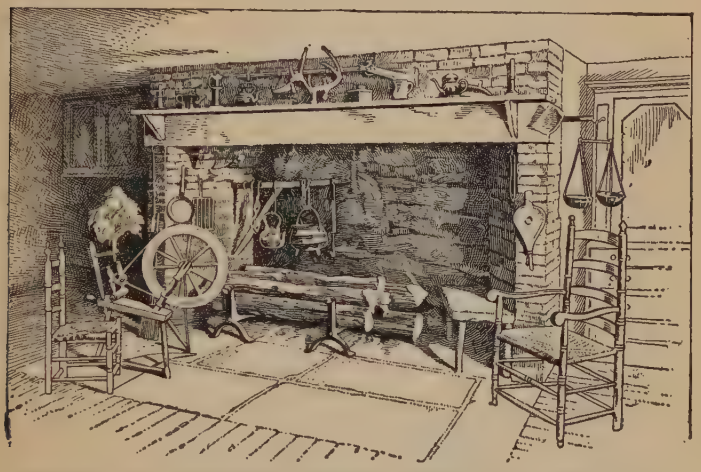
Kind of Rod	Time in Seconds

How does heat travel through metals? Does it travel through all metals at the same rate? Compare copper, brass, aluminum, and iron. When heat travels in this manner we call it *conduction*. Heat travels by conduction at different rates through all kinds of substances, including solids, liquids, and gases. Why do kettles have wooden handles? Why are steam and hot water pipes covered with felt or asbestos? Why does a rug feel warmer than the floor when you step on it with bare feet? Air is a very poor conductor of heat. Explain why woolen underwear is warmer than cotton underwear. Why do double windows make a house warmer in winter? Ice keeps all summer when packed in sawdust. How do you account for this?

Problem 2 — How my kitchen is warmed

Home Problem. — How does heat travel from the kitchen stove to different parts of the room? Take a thin board from a wooden packing box. Cut off a piece a foot long and an inch wide. Ignite this stick. Let it burn for about

a minute. Blow out the flame. Hold the smoking stick just over the hot stove. *Watch the smoke.* Ignite the stick several times to make plenty of smoke. Hold the smoking stick near the ceiling. Hold it near the opposite wall: Near a window. Near the floor. Under the stove. Watch the smoke. Explain why the air over the stove rises. Why does the air near the opposite wall go down? How



Fireplaces were used instead of stoves and furnaces in colonial days

does heat travel from the stove to an opposite corner of the room? What carries the heat? When heat travels by this method we call it *convection.* How do winds carry heat? How does a radiator heat a room?

Draw a rectangle, four inches long and three inches high. Let these lines represent the floor, walls, and ceiling of your kitchen. At the bottom of this rectangle, draw a small square to represent the kitchen stove. Show by arrows how heat travels from the stove to the opposite side of the kitchen. Does heat travel faster by convection, or

by conduction? Why is it colder under the stove than over it? Why is it warmer near the ceiling than near the floor? Where are the coldest parts of your kitchen? Explain.

Problem 3 — How a fireplace warms a room

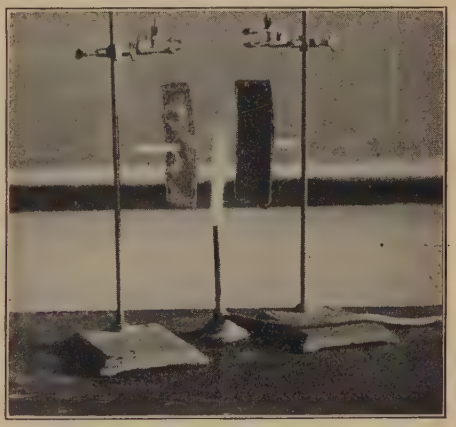
Home Problem. — (*a*) Can a fireplace warm a room by conduction? By convection? Describe how the heat strikes you when you stand before a fireplace. Does it travel fast or slowly? Does it come in straight lines or crooked lines? Hold a cardboard in front of your face. Does heat come through the cardboard? Cover half of your face with the cardboard. Where does the heat strike now? *How does heat travel from the sun to the earth?* Is it carried by air? Does it travel through some substance, by conduction? Do the rays of heat from the sun travel fast or slowly? Do these rays pass through a window? How do you know? Do they pass through a window shade? A straw hat? A parasol? Do these rays travel in straight lines or crooked lines?

(*b*) When there is a bright fire in your heater, open the fire door quickly. Describe how the heat strikes your face. Does it travel quickly or slowly? Cover half of your face with a cardboard. Where does the heat strike? Does this heat travel in straight lines or crooked lines? Does it go around corners? Does it pass through opaque objects, like cardboard? Hold a piece of clear glass in front of your face. Does heat pass through the glass?

When heat travels by this method, we call it radiation. A stove or radiator warms a room by all three methods — *conduction*, *convection*, and *radiation*. Explain how this is possible.

Problem 4 — How color affects heat changes

Class Problem. — (*a*) *Do dull objects heat more quickly than shiny objects?* Cut out two pieces of bright tin, three inches square, from an old can. Flatten them out. Hold one side of one tin square in the flame of a candle or kerosene lamp. Cover it with a coating of black soot. Punch two small holes in each square, near the top, and two inches apart. Pass short pieces of fine wire through these holes and twist the ends. Take two ring stands. With the two wires, suspend a square of tin from each ring stand, so that it hangs evenly, and about six inches above the table. Set the ring stands side by side, so that the flat surfaces of the two squares are directly opposite, and not over four inches apart.



Which piece of chalk will drop first?

Let the sooty side of one tin square and the bright side of the other face each other. Now take two pieces of chalk, an inch long. Drop a little melted paraffin, from a burning candle, on the back of each square of tin. Fasten a piece of chalk to the back of each tin square, by holding it in the melted paraffin. Set a Bunsen burner between the two squares of tin, and equally distant from each. Light the burner, using a blue flame. An alcohol lamp may be substituted for the Bunsen burner. Watch the pieces of chalk.

Which drops first? How do you explain this? Which tin square heats more quickly, the dull one or the shiny one? Will water heat more quickly in a polished teakettle or in a dull one? Why?

(*b*) *Do dull objects cool more quickly than shiny objects?* Take a bright tin can that holds about a quart. Cover the side of this can, halfway around with black soot. Leave the opposite half shiny. Fill this can nearly to the top with boiling water. Now hold both hands close to the can, one hand opposite the black side and the other hand opposite the shiny side.

Hold your hands close to the can, but don't touch it

Which hand feels hotter? Which side of the can gives off heat more rapidly? Does hot water cool quicker in a bright aluminum kettle or a black iron kettle? Why is it better to have the bottom of a teakettle black? Why are stoves and steam pipes black?

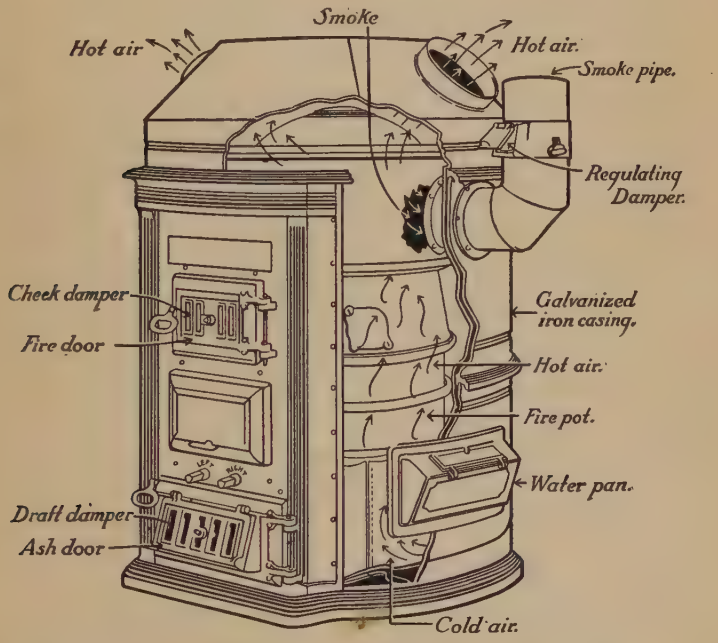
PROJECT II

HOW HOMES ARE HEATED BY HOT AIR

Problems — 1. The furnace and how it works.
2. A hot air heating system.

Problem 1 — The furnace and how it works

A furnace is simply a stove with a galvanized iron casing around it. Cold air passes up between the stove and the



Notice how the air circulates in a furnace. Where does the smoke go?

iron casing, becomes heated, and then passes through large pipes to different rooms of the house.

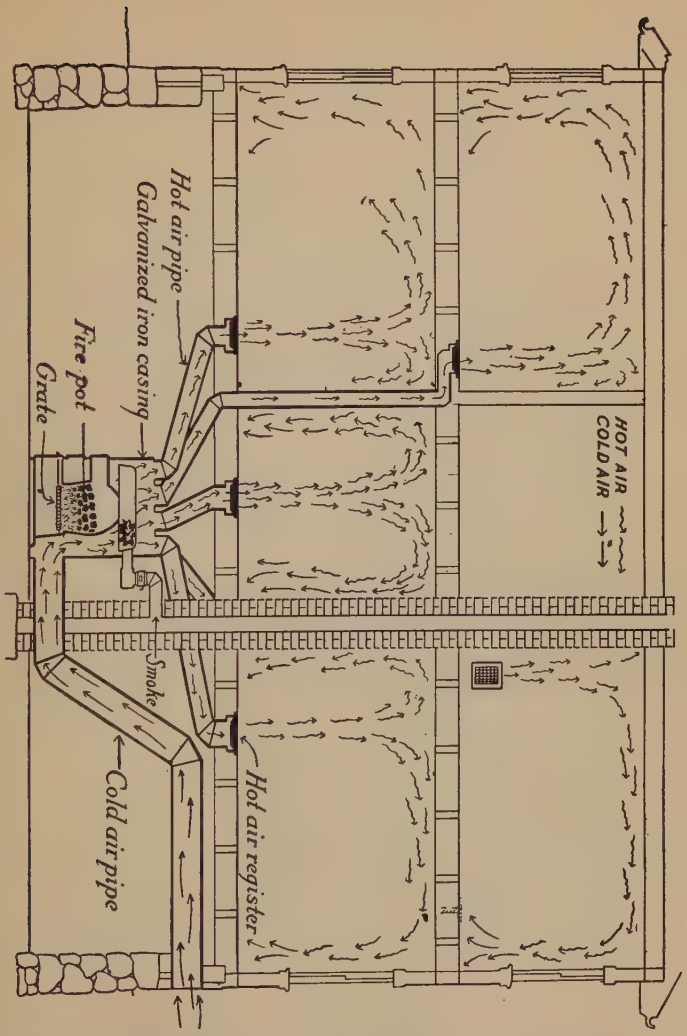
Home Problem. — Is your home heated by hot air? Where is the furnace located? Describe this furnace. What is the purpose of the galvanized iron casing? Where is the cold air box? What is this for? How many pipes lead to the rooms? What are these pipes made of? Why are they so large? Where are the registers in your house? What are these for? How does heat affect air? Why is cold air heavier than warm air? By what method does heat travel from a furnace to the rooms of a house? What carries the heat? Why does hot air come up through the registers?

Problem 2 — A hot air heating system

Home Problem. — If your home is heated by hot air, draw a simple plan showing the furnace, cold air box, hot air pipes, registers, and rooms. Label all parts neatly.

Class Problem. — Study the plan on page 191. How is this furnace made? Where is the cold air box? Why does cold air enter this box? Where does this air come from? Where does it go? What happens to this air when it passes over the hot stove? Locate the hot air pipes. What are these for? Why does hot air go up through these pipes? Notice the registers. Where are they located? What are they for? How does heat travel from the furnace to each room? How is this heat distributed to different parts of a room? Where is the smoke pipe? Why doesn't this smoke go up into the rooms? *What are some of the good points about a furnace?*

Does it take very long to warm a room after you start a fire? Are there any water pipes in a furnace to freeze in winter and cause trouble? *What are some of the bad points about a furnace?* Sometimes the fire box cracks open, or the joints become loose. When this happens, where do some of the poisonous gases go? How often do



How a furnace heats a house.

you have your furnace inspected and the joints cemented? Why does a furnace bring more dust and ashes into the rooms than a hot water heater or a steam heater? Does a furnace heat all the rooms of a house evenly?

PROJECT III

HOW HOMES ARE HEATED BY HOT WATER

Problems — 1. How heat affects water.
2. Is cold water heavier than warm water?
3. How water carries heat.
4. A hot water heating system.

Problem 1 — How heat affects water

Review Problem 1 (*b*), page 108.

Problem 2 — Is cold water heavier than warm water?

Class Problem. — Take two Erlenmeyer flasks of the same size. Be sure that they will hold the same quantities of water. If one flask is heavier than the other, put fine sand in the lighter one until they balance. Fill one flask brimming full of cold water. Fill the other flask brimming full of hot water. Set one flask on each side of platform scales. Do the flasks balance? Which flask goes down? Which flask goes up? Which is heavier, the flask of hot water or the flask of cold water? What are your conclusions? Why does cold water weigh more than warm water?

Both flasks are full of water. Which one is hot?

Problem 3 — How water carries heat

Class Problem. — Set up a glass model to illustrate hot water heating, as shown in the illustration.

Use a lamp chimney for a radiator, a small glass funnel for an expansion tank, and large glass tubing (about $\frac{3}{8}$ of an inch, outside diameter) for pipes. Bend pieces of glass tubing, as shown, and connect them with short lengths

A hot water heating model. Watch the water circulate

of rubber tubing, making a rectangle about one foot high and six inches wide. Push the ends of the glass tubing through the holes of a two-hole rubber stopper. Let one end extend about four inches above the other.

Boil about one quart of water, to drive out the air bubbles. Fill the glass tubing with this water, pouring it into the long arm. Bring one end of the lamp chimney down over the rubber stopper, and force the stopper in tightly. Don't push too hard. You may crack the chimney.

Put an even teaspoonful of sifted sawdust into the lamp chimney. Use powdered carmine if you have it. It works better than the sawdust. Now fill the chimney with boiled water. Push the stem of a glass funnel through the hole in a one-hole rubber stopper. Force this stopper into the top of the chimney, so that water rises part way in the glass funnel. Wipe the glass tubing with a dry cloth. Place a square of asbestos under one corner of the glass rectangle.

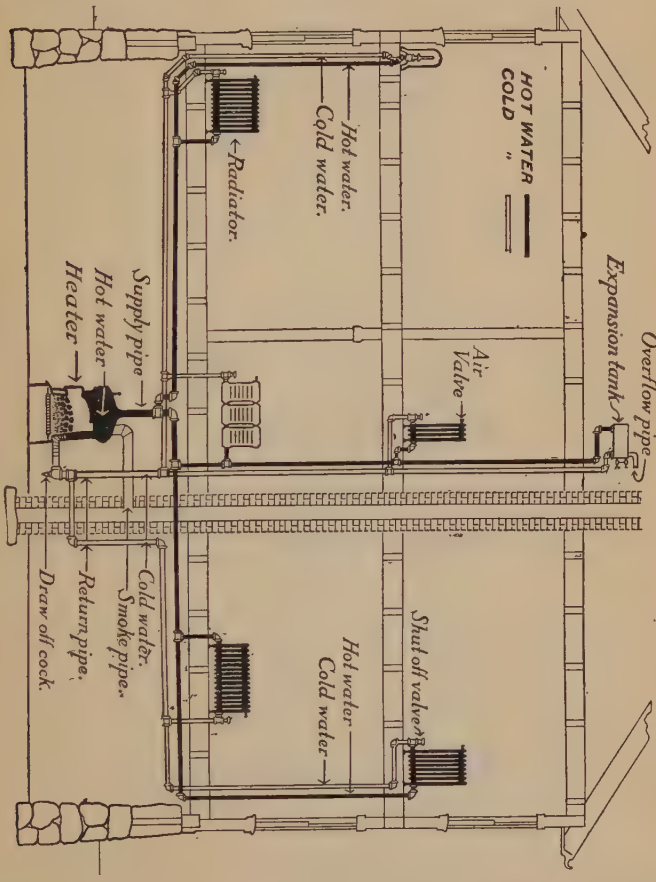
Light a Bunsen burner or an alcohol lamp. Set this under the asbestos square. Heat, slowly and carefully, using a small flame. Watch the sawdust. How does it move in tubing *A*? In tubing *B*? In the lamp chimney? What makes the sawdust move in this direction? How does the water move in tubing *A*? In tubing *B*? In the lamp chimney? What causes this circulation? Which column of water is heavier, *A* or *B*? Why does water go up tubing *A*? Why does it come down tubing *B*? *Watch the glass funnel.* What happens? What causes this expansion? Why is column *A* heavier than column *B*? How does heat travel in this system? What is this method called?

Problem 4 — A hot water heating system

Home Problem. — If your home is heated by hot water, draw a simple plan, showing the heater, radiators, pipes, and expansion tank. Label all parts neatly.

Class Problem. — *Study the plan on page 195.* How is this heater made? Where is the water? Where are the hot water pipes connected? Where are the cold water pipes connected? Where are the radiators? Explain how water flows through these radiators. Why does warm water go up through the pipes? Why does cold water

come down? Notice the air valves on the radiators. What are these for? Where is the expansion tank? What is this for? How does heat travel from the heater to the



How a house is heated by hot water

radiators? How does this heat get out of the radiators? How is it distributed to different parts of a room? *What are some of the good points about a hot water heater?* Does it bring dust or poisonous gases into the rooms?

Water stays hot a long time. What is the advantage of this? Hot water heats a house evenly. Do you consider this a good point? *What are some of the bad points about a hot water heater?* What happens to the pipes and radiators if the water in them freezes? Hot water heats slowly. Can you heat a room as quickly with hot water as you can with hot air? Which costs more to install, a hot water system or a hot air system?

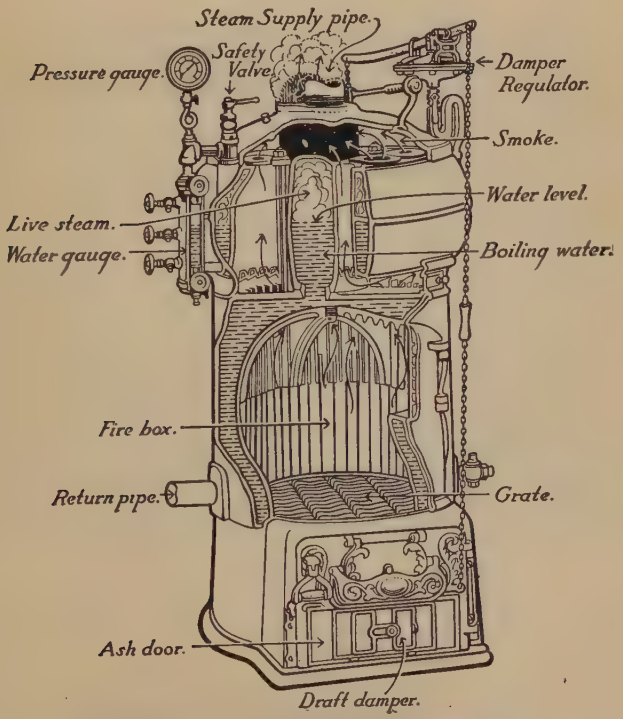
PROJECT IV

HOW HOMES ARE HEATED BY STEAM

Problems — 1. The steam heater and how it works.
2. How steam carries heat.
3. A steam heating system.

Problem 1 —The steam heater and how it works

Home Problem. — Is your home heated by steam? Where is the steam heater located? Describe this heater. Where



A steam heater is only partly filled with water. Why?

is the safety valve? What is this for? How does it work? Where is the water gauge? What is this for? How do you put more water into the heater? Why is it necessary to do this occasionally? Do you keep the heater full of water? Why not? Where is the pressure gauge on your steam heater? How does this work? How many pounds of steam do you usually carry? How many pounds of steam can you carry with safety in your heater?

Problem 2 — How steam carries heat

Home Problem. — What is steam? Can you see it? How is water changed to steam? How can steam travel

Steam carries lots of heat. Feel of the bottom of the sauce pan

from the heater to the radiators of a house? (See Problem 3, page 75.) What happens when steam strikes the cold radiators? *How can steam carry so much heat?* Pour half a pint of cold water into a shallow pan. Set it on a burner

of the gas range. Light the gas. How many minutes does it take for this water to start to boil? Let the water boil until all of it has been changed to steam. How many minutes does it take? Is this steam any hotter than the boiling water? What then becomes of all the heat that is used up?

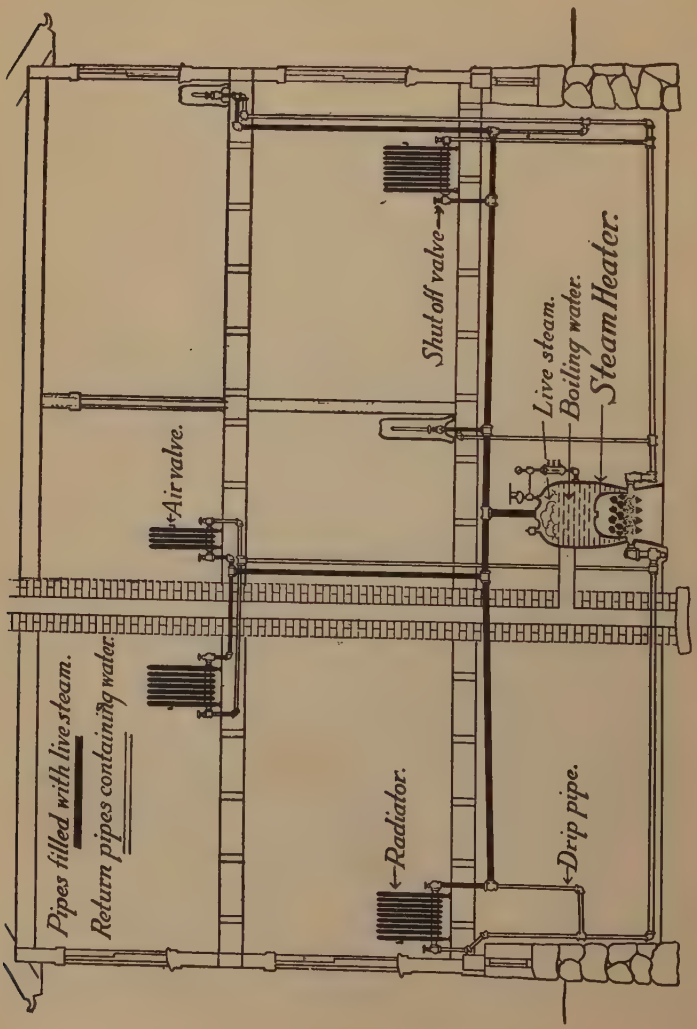
Steam contains large quantities of heat. When a quart of water changes to steam, this steam contains many times as much heat as the quart of boiling water did. *How does steam give up its heat?* Hold a cold sauce pan upside down over the jet of steam coming out of a teakettle spout. What happens to this steam? *Hold one hand on the bottom of the pan.* Why does it feel hot? Where does this heat come from? How does the steam give up this heat?

Problem 3 — A steam heating system

Home Problem. — If your home is heated by steam, draw a simple plan, showing the heater, safety valve, water gauge, pressure gauge, radiators, valves, and pipes.

Class Problem. — *Study the plan on page 200.* Describe the heater shown in this plan. Point out the safety valve. The water gauge. The pressure gauge. Is this heater kept full of water? How does steam go from the heater to the radiators? How does this steam carry heat? How can it carry so much heat? Notice the air valves on the radiators. What are the *cold* pipes and radiators filled with? Can steam come into the radiators when the valves are closed? Why not? What is the hissing sound when you first open an air valve? Some of these valves are automatic. They open and close themselves. What happens when live steam strikes the cold radiators? Where does this water go? Where does the heat from the steam go? How

can this heat get out of the radiators? *What are some of the good points about a steam heater? What are some of the bad points?*



How steam heats our homes

PROJECT V

A STUDY OF ILLUMINATING GAS

Problems — 1. How coal gas is made.
2. Some peculiarities of illuminating gas.
3. What illuminating gas is composed of.
4. How illuminating gas burns.
5. A study of the gas range.
6. How to save gas in cooking.

Problem 1 — How coal gas is made

Class Problem. — Secure a good quality of gas coal from the nearest gas plant. If this cannot be obtained, use bright, clean lumps of soft coal.

Grind a small quantity of soft coal to a powder. Put an inch and a half of this into a test tube. Bend a piece of glass tubing as shown in the picture. Heat one end and draw it out to a fine point. Break it, leaving a small hole.

When you make coal gas heat the test tube evenly

Push the opposite end of the glass tubing through the hole in a rubber stopper. Force the stopper into the mouth of the test tube. Heat the coal evenly and slowly over a Bunsen flame. Hold a burning match over the tip of the glass tubing. *Describe what you see.* What is driven off from the coal? Why doesn't this gas burn in the test tube? *Break the test tube.* Describe the substance you find there. What is this substance? Why is it left in the test tube? How is coke made? What are the pores in coke? Examine the inside of the glass tubing. Describe the substance you find there. Note the odor. What is this substance? Where do the following products come from?

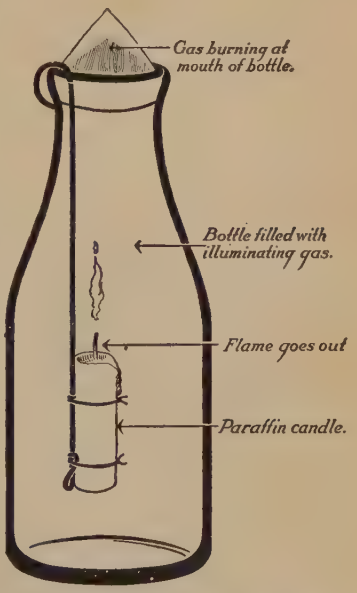
Ammonia	Saccharine	Aniline dyes
Creosote	Carbolic acid	Tar paper

Is it possible to make gas from wood? Why is hard coal unsuitable for making gas? How is gas stored? Why is it necessary to purify illuminating gas? Do you use illuminating gas at home? Where is this gas made? What is water gas? Why does coke burn without a yellow flame?

Problem 2 — Some peculiarities of illuminating gas

Class Problem. — (*a*) *What is the color of illuminating gas?* Fill a quart milk bottle with illuminating gas as follows: Attach a piece of rubber tubing to the gas pipe. Now fill the milk bottle with water. Pour about an inch of water into a shallow pan. Invert the bottle of water in the pan. Slip an end of the rubber tubing under the mouth of the bottle. Turn on the gas. Why does the water go out of the bottle? What is the bottle filled with now? Examine the gas in the bottle. What color is it? Can you see illuminating gas? Has it any odor? Have you any proof that illuminating gas is harmful to breathe?

(*b*) *Does illuminating gas support combustion?* Place a bottle full of illuminating gas on the table. Put a tin cover over the mouth of the bottle. Now fasten a candle to a piece of wire. Light the candle. Lower the burning candle into the bottle of gas until it nearly touches the bottom, and replace the cover. Does the candle burn now? Will illuminating gas support combustion? How do you explain this?



Why does the gas burn only at the mouth of the bottle?

(*c*) *Will illuminating gas burn?* Fill a quart milk bottle with the gas. Place it on the table. Hold a burning match just over the mouth of the bottle. What happens? Now place a tin cover on the top of the milk bottle. *What happens?* Repeat this several times, until all the gas in the bottle is burned. Will illuminating gas burn? Why does the gas burn at the mouth of the bottle? *Light the gas at the end of the gas pipe.* Where does the gas burn? Why doesn't it burn inside the pipe?

(*d*) *Pour an inch of water into a quart milk bottle.* Hold the palm of one hand tightly over the top of the bottle, and invert it into a basin of water. Slip one end of a piece of rubber tubing, attached to the gas pipe, under the mouth of the bottle. Turn on the gas, and force all the water out of the bottle. Hold one hand tightly over the mouth of

the bottle and shake. Set the bottle upright on the table. Remove the hand from the mouth of the bottle and promptly bring the flame of a match just over the bottle. *What is the result?* Repeat the experiment, using different mixtures of gas and air. Why do gas burners sometimes "back fire" when you first light them? Does unmixed gas explode?

Problem 3 — What illuminating gas is composed of

Class Problem. — (*a*) Light a Bunsen burner. Close the air ports, so that the flame is yellow. Hold the bottom of a clean white dish in the yellow flame for a few seconds. Examine the bottom of the dish. *What do you find?* What is this substance? Where does it come from? What does this show concerning the composition of illuminating gas?

Where does the water come from?

(*b*) *Open the port holes of a Bunsen burner, so that the flame is blue.* Place a clean, dry, gallon battery jar outside the window for a few minutes. Now bring the mouth of the battery jar down over the blue flame. Hold it there for a few moments. What forms on the inside of the jar? What is this substance composed of? Where does the hydrogen come from? Where does the oxygen come from? What happens to these elements when the gas burns?

What does this show concerning the composition of illuminating gas?

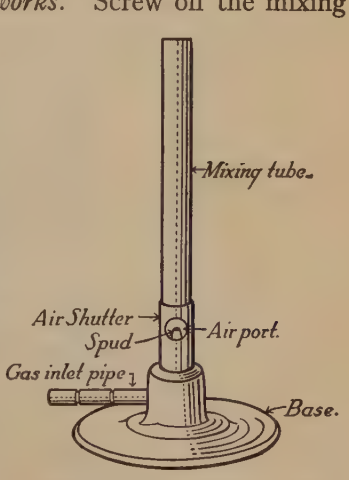
(*c*) *What becomes of illuminating gas when it burns?* What collects on the inside of the battery jar when you hold it over the blue flame? What collects on the inside of the windows when you use the gas range for cooking? What is one of the products of combustion of illuminating gas?

Fill a quart milk bottle with illuminating gas. Hold a burning match over the mouth of the bottle. Repeat several times, until all the gas is burned. Now pour half an inch of clear lime water into the bottle. Tell what happens. What gas is formed when illuminating gas burns? Where does the carbon come from? Where does the oxygen come from? What happens to these elements?

Problem 4 — How illuminating gas burns

Class Problem. — (*a*) *Examine a Bunsen burner.* Point out the air ports, air shutter, and mixing tube.

(*b*) *How a Bunsen burner works.* Screw off the mixing tube. Examine the base, inlet pipe, spud, and gas orifice. Note the size of the gas orifice. Connect a piece of rubber tubing from the inlet pipe of the burner to the gas pipe. Open the gas cock. Light the gas at the orifice. Describe how it burns. Screw the mixing tube to the base again.

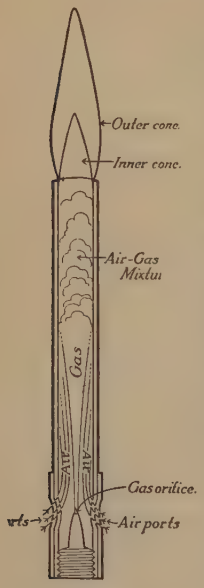


A Bunsen burner showing parts

(*c*) *Close the air shutter.* Light the gas. What color is the flame? Hold a clean

white dish in the flame for a few seconds. What collects on the dish? How do you account for this? Where does the gas obtain the necessary air for combustion?

(*d*) *Open the air shutter.* What color is the flame now? How many parts do you see in the flame? What is the outer cone? What is the inner cone? Hold a smoking splint near the air ports. What causes the air to rush into the ports? How do the sizes of the air ports and gas orifice compare? What are the relative quantities of gas and air in the mixing tube? Does the blue flame obtain its air supply from any other source? Hold a clean white dish in the flame for a few seconds. Do you find any carbon on the dish? How do you account for this? What kind of flame do you use on the gas range at home?



A Bunsen burner in action

(*e*) *Why a gas flame is yellow.* Light the Bunsen burner. Open the air ports, so that the flame is blue. Grind a lump of charcoal to a fine powder. Sprinkle a teaspoonful of this powder in the blue flame. What color does the flame become? What is charcoal composed of? What happens to these tiny particles of carbon when you sprinkle them in the flame of the Bunsen burner? What is the color of a lump of coal when it burns? Close the air shutter again. Hold a clean white dish in the flame for a few seconds. What collects on the dish? Can you tell now why the flame is yellow? Why does the flame become blue, when the air ports are open?

(*f*) *Why a blue flame is used on the gas range.* Take a piece of glass tubing two feet in length. Cut it in the middle. Place two similar Bunsen burners on the table about eight inches apart. Make the flame of one burner blue, the other flame yellow. Support the ends of the two pieces of glass tubing, at the same height, and about two inches above the tops of the burners. At the same moment, place the blue flame under the center of one piece of glass tubing, and the yellow flame under the center of the other piece of glass tubing. Note the time it takes for each flame to bend the glass.

What is the black stuff on the plate? Where does it come from?

Time for blue flame, —— seconds

Time for yellow flame, —— seconds

Which flame is hotter, the blue or the yellow?

Which flame is the hotter? How do you account for

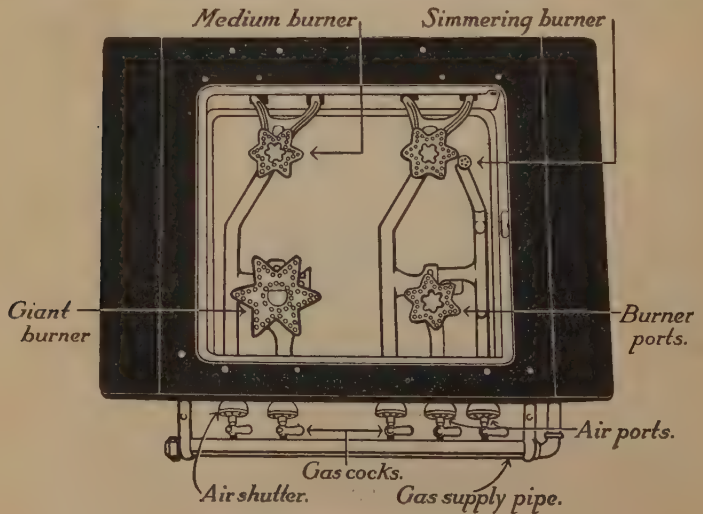
this? Why do you use a blue flame on the gas range? Why is no carbon given off from the blue flame? What color is the flame of a Welsbach gas lamp? Why is a yellow flame used in an open gas jet? Why does soot sometimes form on the bottoms of kettles used on the gas range? How can you remedy this trouble?

Problem 5 — A study of the gas range

Home Problem. — (*a*) *Examine the gas range at home.* Locate the following parts:

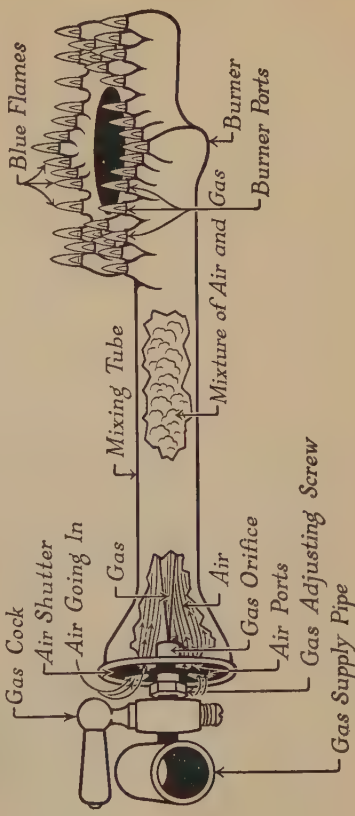
Top burners	Gas cocks	Oven burners
Giant burner	Air shutters	Pilot lighter
Medium burner	Air ports	Baking oven
Simmering burner	Gas ports	Broiling oven

(*b*) *Light one of the top burners.* What color is the flame? Why is a blue flame used on a gas range? How many distinct parts do you see in each gas flame? What is the inner



Top of gas range, showing burners

cone? What is the outer cone? Hold a smoking wooden splint in front of the air ports. What does this prove? What causes air to enter the air ports? Why is it necessary to mix air with the gas? Place a kettle of cold water over this burner. After a few seconds examine the outside of the kettle. What do you find? Where does this water come from? What effect does this have on the air of the room?



This shows how the burners on your gas range work

Close the air shutter of one of the top burners. Use a small screw driver to do this. Light the burner. What color is the flame? Place a kettle of water over the flame for a few minutes. Examine the bottom of the kettle. What do you find? Why is this substance formed? What is the cause of soot on kettles? How can this trouble be remedied?

(*c*) *Light the oven burners.* What is the proper way to do this? Why do you wait a moment, after opening the gas cock, before you apply the match? Why do you open the oven doors when lighting the oven burners? Explain

how the gas and air are mixed. Why are the air ports so much larger than the gas orifice? What color are the flames? Why does the inside of the oven become wet when the oven burners are first lit? Do you find any rust inside the oven? What is the cause of this? Why is it a good plan to leave the oven doors open for a few minutes after turning off the gas?

Problem 6 — How to save gas in cooking

Home Problem. — Take two open kettles of the same size. Fill each kettle half full of water. Light the two medium-sized burners of the gas range. Set a kettle of water over each burner. Peel four small potatoes of the same size. Cut them in halves. Wait until the water in each kettle begins to boil vigorously. Now drop four pieces of potato in each kettle. Keep the gas cock of one burner wide open, so that the water boils vigorously. Partly close the gas cock of the other burner, until the water boils slowly. Note the time when you drop the potatoes in the two kettles. Examine the potatoes in each kettle occasionally with a small fork to determine when they are cooked soft. How long does it

This potato is cooked. How about the ones in the other kettle?

take to cook the potatoes in each kettle? Which burner uses the more gas? Which kettle contains the greater quantity of water when the potatoes are cooked?

Class Problem. — Take two small kettles of the same size. Pour the same quantity of water into each kettle, filling each about half full. Light three Bunsen burners. Set two Bunsen burners under kettle *A*, and one Bunsen burner under kettle *B*. Wait until the water in each kettle boils vigorously. Now drop several pieces of potatoes of the same size in each kettle. Examine the potatoes occasionally to determine when they are cooked soft. Compare the two kettles as follows:

	Kettle *A*	Kettle *B*
1. Number of Bunsen burners		
2. Quantity of gas burned		
3. Amount of heat generated		
4. How the water boils		
5. Time it takes to cook the potatoes		
6. Amount of water left		

What cooks the potatoes? Do the potatoes cook any quicker in kettle *A*? With a thermometer take the temperature of the water in each kettle.

Why is the temperature of the water in each kettle the same? Which kettle has the greater quantity of water left at the end of the experiment? Compare the amounts of gas burned under the kettles. How does the cost of cooking potatoes in the two kettles compare?

FACTS EVERY ONE SHOULD KNOW ABOUT HEATING

Conduction. — Heat travels by three methods: by conduction, by convection, and by radiation. Hold one end of an iron rod in the fire. Heat soon travels along the rod to the opposite end by a method called conduction. Now an iron rod is made up of countless millions of tiny particles of iron, so small that they are invisible, even under the most powerful microscope. Not only iron, but every material thing, including every solid, every liquid, and every gas, is made up of its own kind of these tiny particles. When a substance is heated, the particles of which it is composed are set in motion, and move rapidly back and forth. The hotter the substance becomes, the faster they move. As one end of the iron rod is heated by the fire, the particles of iron in this end of the rod are set in motion. These bump against the particles next to them and set them in motion. This action continues throughout the entire length of the iron rod.

Some substances conduct heat much faster than others. Of the metals, silver is the best conductor of heat. Copper comes next. Then come in order, aluminum, brass, zinc, tin, and iron. Water is a poor conductor of heat. Wood is also a poor conductor of heat. For this reason wooden handles are used on stove pokers and kettles. Still air conducts heat very slowly. We use double windows, with an air space between, to keep our houses warm in winter. We also wear woolen clothing in winter. The many air spaces between the loosely woven fibers of woolen cloth make it a poorer conductor of heat than cotton or linen. Thermos bottles and fireless cookers are constructed so that heat passes through the sides very slowly. When you get out of bed on a cold morning you like to step on a rug. It

feels warmer to your bare feet than the floor. Now the rug is just as cold as the floor. The floor feels colder because it is a better conductor of heat than the rug, and therefore takes heat away from your bare feet faster. This makes your feet feel cold.

Convection. — The second method by which heat travels is called convection. Heat is carried by moving currents of warm air or warm water from one place to another. Warm ocean currents, like the Gulf Stream, carry heat for thousands of miles. Warm winds coming from the south bring heat to colder northern regions. We frequently heat our homes by convection. Hot air and hot water carry the heat from the basement to the different rooms of a house.

Radiation. — The third method by which heat travels is called radiation. We get heat from the sun by this method. The sun's rays travel through space to the earth, a distance of over 90,000,000 miles, at the rate of 186,377 miles per second. These rays pass through air, glass, or any other transparent substance without heating it. In fact, some opaque substance, such as soil, rocks, or wood, must first absorb these rays, before any heat can be felt. Feel of a window pane when the sun shines through it. The glass is cold. Now feel of the window sill, where the sun strikes it. The wood is warm. Some of the sunbeams have been absorbed by the wood and changed into heat. These facts explain why it grows colder as you go up. A few miles above the earth the temperature, even in summer, is many degrees below zero. The tops of high mountains are covered with snow and ice the year round.

Dull or dark objects absorb radiated heat much faster than shining or light-colored objects. Water heats faster in a kettle with a black bottom. You have noticed in

winter how quickly particles of soot melt the snow under them and make little holes. Snow melts faster around a tree than it does in an open field. Black soil heats quicker than light sandy soil. On the other hand, dull or dark-colored objects lose heat faster than shiny or light-colored objects. Water stays hot in a bright aluminum kettle much longer than it does in a black kettle. Thermos bottles are shiny, to help them hold the heat. A black or bronze radiator gives off much more heat by radiation than one painted a light color. Light sandy soil cools off quicker at night than dark soil.

Heating Buildings. — The many improvements in heating, since the times of our grandparents, have added much to the comforts of home life. During the cold days of winter, we are not compelled to huddle around an open fire to keep warm, with clouds of smoke blowing into our eyes, and our backs freezing cold. We build a fire in the basement and heat is carried by air, water, or steam to every room in the house.

Each of the present-day systems of heating has certain advantages and disadvantages.

Furnaces cost the least to install. They are easy to operate. Hot air comes up through the registers a few minutes after you start a fire. They are especially economical in the late fall and early spring when you need only a little heat to warm the rooms. On the other hand, the air from furnaces is very dry. It parches the throat and cracks the furniture. The hot air is distributed unequally. Some rooms are cold and others are too hot. Dust and ashes come up through the registers. Sometimes the joints of the furnace become loose, or the fire dome cracks, allowing poisonous gases to escape into the rooms. Hot water is an excellent system of heating. It gives a

steady heat which is distributed evenly to all the rooms. Care must be taken that the pipes and radiators do not freeze in winter and burst.

Many homes to-day are heated by steam. This does not give as even a heat as hot water, but will heat a house warmer in zero weather. Heat is distributed by steam in an interesting way. When water changes to steam, it takes up much more room. It also absorbs a large quantity of heat, without getting any hotter. When the expanding steam fills the radiators, it condenses back to water and gives up heat. Water formed in this way flows back through the pipes into the heater and is again changed into steam. When steam condenses inside a radiator, the water formed takes up a much smaller space, making room for more steam to flow in.

Care of Heating System. — To get the best results from any heating system proper care is needed. Few people realize how much heat is wasted with careless management. Experts tell us that in the majority of homes to-day more than half the heat is lost. It goes up the chimney, or is thrown away in unburned fuel. Some of the following rules may help you to get better results from your own heating system at home.

1. Shake down the fire twice a day, in the morning and at night.
2. Always leave a thin layer of ashes on the grates.
3. Clean out the ash pit every day.
4. Sift your ashes.
5. Remove clinkers and slate from the grate bars.
6. Keep the fire pot full of fuel. A thin dirty fire wastes fuel.
7. Keep the fire door closed.
8. To make the fire burn fast, open the damper in the

ash door and the turn damper in the smoke pipe, and close the regulating damper in the smoke pipe.

9. To check a fire close the ash door damper, partly close the turn damper, and open the regulating damper in the smoke pipe.

10. Keep a clean steady fire. Don't force it at one time, and then let it almost go out.

11. Don't try to burn too large sizes of coal. In ordinary heaters the stove size usually gives better results than egg or furnace coal.

12. Clean out the chimney and smoke pipe at least once a year.

13. Open the clean-out doors and brush off the heating surfaces at least once a month.

14. Cover the pipes in the basement with felt or asbestos.

15. Keep the cold air box of furnaces wide open.

16. Examine the fire pots of furnaces once a year. Fill cracks or loose joints with furnace cement.

17. Keep your hot water system filled with water. Watch the gauge in the expansion tank.

18. Open the pet-cocks of hot water radiators occasionally to let out the air.

19. Keep the boiler of the steam heater filled with water to the proper level. Never fill an empty steam boiler when it is hot.

20. Make sure that the air valves on your steam radiators work properly. No steam can enter a radiator until the air is allowed to escape.

21. Keep several thermometers in the house. Look at them occasionally.

22. Don't heat your house too hot. Sixty-eight degrees Fahrenheit is warm enough for most people.

Gas. — Most of the gas used in the United States is either coal gas, water gas, or a mixture of these two gases. Coal gas is made from soft coal, by heating it in a closed retort. Ammonia, coal tar, and other valuable products are driven off with the gas. Coke is left in the retort. This is removed and sold as a fuel. Coal gas is a mixture of several gases, chiefly marsh gas, carbon monoxide, and hydrogen. Water gas is made by forcing live steam through layers of red hot coke. The hot coke breaks up the water of the steam into hydrogen and oxygen. Hydrogen passes off. The oxygen combines with carbon from the coke and passes off as carbon monoxide. Hence, water gas is a mixture of two gases, hydrogen and carbon monoxide.

Illuminating gas is a colorless invisible mixture of gases, with a peculiar odor like gasoline. Since illuminating gas contains carbon monoxide, it is a deadly poison. When a burning candle is lowered into a bottle filled with illuminating gas, the flame goes out and the gas burns around the mouth of the bottle. Cover the mouth of the bottle with a cardboard, and the burning gas is extinguished. These experiments show that illuminating gas does not help other things burn. In fact, it puts out fire. Like other fuels, it needs oxygen to burn. A plate held in the yellow flame of a gas burner is covered with black soot. This is carbon. It comes from the burning gas. This shows that illuminating gas contains carbon. Clear lime water becomes milky when shaken up in a bottle in which illuminating gas has been burned. This shows that carbon dioxide is given off when this gas burns. It is formed by the combining of carbon and oxygen. Perhaps you have noticed drops of water collect on the windows when you light the gas range on a cold morning. These drops of water come from the burning gas. It is formed by the

hydrogen in the gas combining with oxygen of the air. Two quarts of hydrogen combine with one quart of oxygen to form a few tiny drops of water.

You have examined a Bunsen burner. Its construction is similar to that of the burners on your gas range at home. When the air ports are closed the gas burns with a yellow flame. Open the air ports and the flame immediately changes to a blue color. The blue flame is much hotter than the yellow flame. It is also cleaner, because it does not give off particles of carbon. The flames of your gas burners at home should be blue. No soot should form on the bottoms of pans or kettles. Keep the air ports wide open. The tiny holes in the burners frequently become clogged with dust and grease. Remove the burners at least once a month, and wash them thoroughly with boiling water and washing soda. Sometimes when you light the gas, a slight explosion takes place. The flame "strikes back" and ignites the gas at the orifice. This is called "back firing." It is caused by too much air, or not enough gas. To remedy this trouble close the air shutters a little, to admit less air.

Many people waste gas. With proper care their gas bills would be much lower. When you cook vegetables or any other foods in boiling water, partly close the gas cock as soon as the water starts to boil. Water boiling slowly is just as hot as water boiling violently. The extra heat only evaporates more water. It doesn't cook the food any quicker. Don't use a large gas burner when you can use a small one, for the large burners consume more gas. A close-fitting cover on a kettle also saves heat and gas. Bake as many foods as you can in the oven at the same time. Read your gas meter frequently. Check your gas bills each month.

CHAPTER VII

HOW WE LIGHT OUR HOMES

THE rays of sunlight that shine so cheerfully through your bedroom window in the morning have just reached the end of a long, long journey. They have traveled through space, a distance of over 90,000,000 miles, very much faster than the fastest express train. All day long these rays of light are very active. They drive away darkness and make objects visible, so that you and I can see. They pass through tiny drops of water and scatter in the beautiful colors of the rainbow. They search out the living germs of deadly diseases in thousands of dark corners and kill them. They flash through the lenses of cameras, with lightning speed, and paint many pretty pictures. They strike the surfaces of countless green leaves and help to manufacture the foods that you and I eat. These are only a few of the many blessings that sunlight contributes to your welfare and mine. After the sun sets man tries to drive away the darkness with artificial lights. The great improvement in lighting, from the smoky pine knot and tallow candle of early times to the remarkable brilliance of the present day Welsbach and Mazda, is a marvelous story of invention and progress. In the following chapter, we want you to study some of the interesting facts about lighting — how a candle gives light, kerosene lamps and how they burn, how we light our homes with gas lamps, and how we use electricity for lighting.

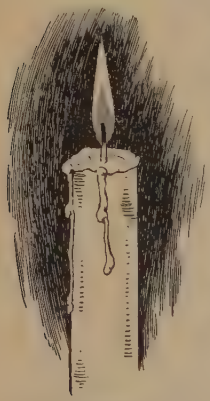
PROJECT I

A CANDLE AND HOW IT BURNS

Problems — 1. How a candle burns.
2. How a candle gives light.
3. What becomes of a candle when it burns.

Problem 1 — How a candle burns

Class Problem. — (*a*) *Light a paraffin candle.* Watch it burn. How many parts do you see in the flame? What is the shape of each part? What color is the inner cone? What color is the outer cone? Notice the hollow at the top of the paraffin. What makes this hollow? What is it filled with?



What changes take place in the paraffin before it burns?

(*b*) *What is the flame of a candle?* With a quick breath, blow out the flame of a candle. Hold a burning match just over the wick. Repeat several times. What happens? What is the flame of a candle? What is the outer cone? What is the inner cone? How does paraffin change before it burns? Why does a candle burn for so long a time? Why does the flame go out when you blow at it?

Problem 2 — How a candle gives light

Class Problem. — Hold the bottom of a clean white plate in a candle flame for about a minute. Examine the bottom of the plate. What do you find? What is this substance? Where does it come from? Grind a small piece of charcoal to a fine powder. Sprinkle this powder

into the blue flame of a Bunsen burner or alcohol lamp. Why does the blue flame change to yellow? What happens to the particles of carbon? What color do they become?

How can black soot come from white paraffin?

Does a burning candle give off particles of carbon? What color do these particles become when they burn? Why is a candle flame yellow? Why does it give light?

Problem 3 — What becomes of a candle when it burns

Class Problem. — (*a*) Hold a dry, clean milk bottle outside the window until it is cold. Lower a burning candle into the bottle with a piece of wire. What collects on the inside of the bottle? What is water composed of? Where does the oxygen come from? The hydrogen? What happens to these elements when the candle burns? Is a candle flame wet or dry? Can you see any water coming out of the flame? Why do you use a *cold* milk bottle?

(*b*) *Rinse the milk bottle several times with water.* Pour an inch of clear lime water into it. Does the lime water

stay clear? Now lower a burning candle into the bottle with a piece of wire. When the flame goes out, remove the candle. Hold one hand over the top of the bottle and shake. What happens to the lime water? What gas turns lime water milky? Where does this carbon dioxide come from? How is it formed? Where does the oxygen come from? The carbon? What happens to these two elements when the candle burns? *What becomes of a candle when it burns?*

PROJECT II

A KEROSENE LAMP AND HOW IT BURNS

Problems — 1. The parts of a kerosene lamp.
2. How a kerosene lamp burns.
3. How a kerosene lamp gives light.
4. What becomes of kerosene when it burns.
5. How to use a kerosene lamp.

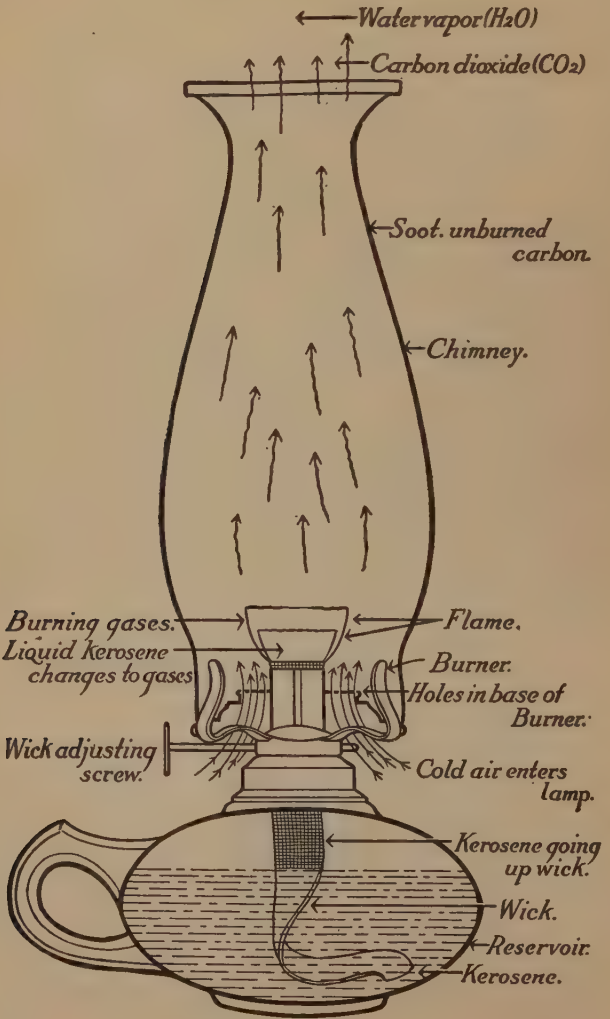
Problem 1 — The parts of a kerosene lamp

Home Problem. — Examine a kerosene lamp at home. Why do you use a chimney on a lamp? Why is it made of glass? Have you a shade on your lamp? What is this for? How do you fill your lamp? Do you fill it while it is burning? Screw off the metal burner and examine it. Notice the little holes in the base of the burner. What are these for? How is the wick attached to the burner? How do you move the wick up or down? Why do you do this? What is the wick made of? How does kerosene go up the wick?

Problem 2 — How a kerosene lamp burns

Home Problem. — How does kerosene go up the wick? Barely cover the bottom of a saucer with black ink. Put a lump of white sugar in the ink. What happens? Where does some of the ink go? Is a lump of sugar solid? Explain how the sugar absorbs ink. Put a large drop of ink on a smooth white sheet of paper. Lay a blotter on the ink spot. What happens? Put a second drop of ink on the sheet of paper. Lay a smooth piece of writing paper on this ink spot. What happens? Examine the blotter. How does it absorb ink? Why doesn't the

writing paper absorb ink? Examine the wick of your lamp. How is it made? Explain how kerosene goes up the wick.



A kerosene lamp in action

Class Problem. — (*a*) *Does a kerosene lamp need oxygen to burn?* Light a lamp. Put on the chimney. Turn down the wick so that the flame is low. Hold two burning matches under the metal burner, one match under one side of the burner and one under the opposite side. Repeat several times if necessary. Watch the flame of the lamp. Why does it go out? How does a lamp get the air it needs

How can fire put out fire?

to burn? Where does air enter the lamp? How do the burning matches affect this air?

(*b*) *What makes the draft in a kerosene lamp?* Relight the lamp and put on the chimney. Hold a smoking wooden splint just under the metal burner. Where does the smoke go? What carries the smoke up the chimney? How does the flame affect the air inside the chimney? Why does this air weigh less than the outside air? Explain why cold air goes into the lamp. Why does warm air go up the chimney? Why is the draft of a lamp stronger when you make the flame larger?

Problem 3 — How a kerosene lamp gives light

Class Problem. — (*a*) What is the flame of a kerosene lamp? Light a lamp. Don't put on the chimney. Turn the wick up high to make a big flame. Have a burning match ready. With a forceful breath blow out the flame.

The inside of a flame is a gas factory

Now quickly hold the burning match several inches above the wick. Repeat a number of times. What happens? Why does the flame travel back to the wick? What is the flame of a lamp? What happens to kerosene before it starts to burn?

(*b*) *How many parts are there in a flame?* Relight the lamp. Examine the flame. How many parts do you see?

What is the dark central part of the flame? What is the bright outer part? Take a piece of glass tubing, about one inch long. With forceps hold it obliquely, with one end in the dark central part of the flame. Bring a burning match just over the other end of the glass tubing. What happens? Explain. What is the dark central part of any flame? Is the center of a flame hot, or cold? Why does this gas burn when it reaches the outside of a flame?

(*c*) *Why does a flame give light?* Hold a clean white plate in the flame of a kerosene lamp about a minute. Examine the plate. What do you find? What is this black substance? Where does it come from? What color is the burning carbon in coal? Coke? Charcoal? Explain how the tiny particles of burning carbon in a flame produce light.

Problem 4 — What becomes of kerosene when it burns

Class Problem. — (*a*) *Take a clean, dry lamp chimney.* Set it outside the window until it is cold. Light a lamp. Turn down the wick, making a low flame. Place the cold chimney on the lamp. Watch it for a few moments. What collects on the inside of the chimney? Where do these drops of water come from? What is water composed of? How is water formed when kerosene burns? Where does the oxygen come from? The hydrogen? What happens to these two elements?

(*b*) *Remove the chimney and set the burning lamp into a large glass jar.* Hold a cardboard over the top of the jar until the flame goes out. Remove the lamp and pour a little clear lime water into the jar. Shake vigorously. What happens to the lime water? What gas turns lime water milky? How is this gas formed in the jar? Where

does the oxygen come from? The carbon? What happens to these elements when kerosene burns?

Problem 5 — How to use a kerosene lamp

Home Problem. — (*a*) *Filling the lamp.* How do you fill a kerosene lamp? Do you ever fill it while it is burning? Why is this practice dangerous? Do you wait until the kerosene is nearly gone before you refill a lamp? What

Keep your lamps clean and well trimmed

may happen if the kerosene gets too low? What causes this explosion?

(*b*) *Trimming the wick.* Why is it necessary to keep the wick trimmed? How do you do this? Why does a steady flame give better light than a flickering flame?

Class Problem. — (*a*) *Cleaning the burner.* Have you noticed the small holes in the base of the burner? What are these holes for? Turn back the metal cap. Sprinkle a thin layer of sand or salt over the holes. Light the lamp and put on the chimney. What happens? Why does the

flame smoke? Why does a lamp burn better when the burner is kept clean?

(*b*) *Adjusting the flame.* Clean the burner. Relight the lamp and put on the chimney. Turn up the wick so that the flame smokes. What collects on the inside of the chimney? Where does this carbon come from? What becomes of carbon when it burns? What element does it combine with? What gas is formed? Why does carbon collect inside the chimney? Why doesn't *this carbon* burn? Why does a lamp smoke when the wick is turned up too high? *Clean the chimney.* Turn down the wick, so that the lamp burns with a bright steady flame. Does this flame smoke? Does it give off any carbon? What becomes of the carbon? Why does it burn? Why does this flame give a better light than a smoky flame? Which flame is more expensive?

PROJECT III

HOW WE LIGHT OUR HOMES WITH ILLUMINATING GAS

Problems — 1. The parts of a gas lamp.
2. How a gas lamp burns.
3. How a gas lamp gives light.
4. How to adjust a gas lamp.
5. How gas is measured.
6. The cost of gas.

Two general types of gas lamps are sold to-day: those with open yellow flames, and others with mantles. Open flame lamps use more gas and give less light than mantle lamps. There are many different kinds of mantle gas lamps on the market. Some of these have upright burners, others have inverted burners. At least three kinds of mantle gas lamps should be studied under this project. The following lamps are selected as the best present types for study:

The Junior Welsbach
The C. E. Z.
An inverted gas lamp

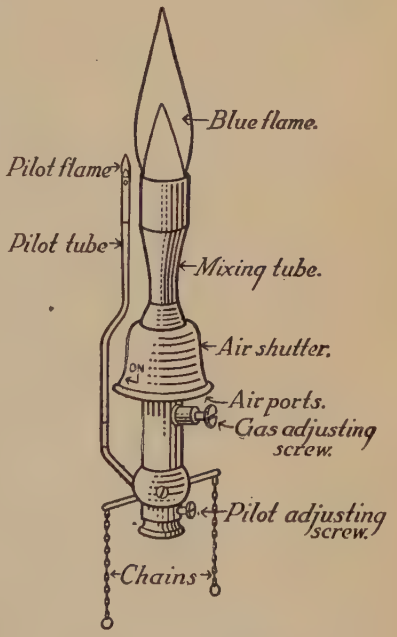
Take up all three types, under each of the first four problems, in the order named. Fasten the lamps with a clamp to a ring stand, and connect them to the gas pipe with rubber tubing.

Problem 1 — The parts of a gas lamp

Class Problem. — Examine several kinds of mantle gas lamps. Point out the following parts:

The gas adjusting screw
The primary air ports
The air shutter
The chains
The pilot adjusting screw
The pilot tube
The mixing tube
The mantle

Turn the gas adjusting screw in and out. What does this screw do? Open and close the air shutter. How does it work? What is the purpose of the air shutter? Point out the pilot tube. What is it for? Why is it made so small? How does the pilot adjusting screw work? Examine a gas mantle. *Describe it.* How is a gas mantle made? Why does it break so easily? How can a gas mantle give light? Have you any gas lamps at home? Make a careful drawing of one of these lamps. Label all parts neatly.



A C. E. Z. burner

The complete lamp is shown on page 236

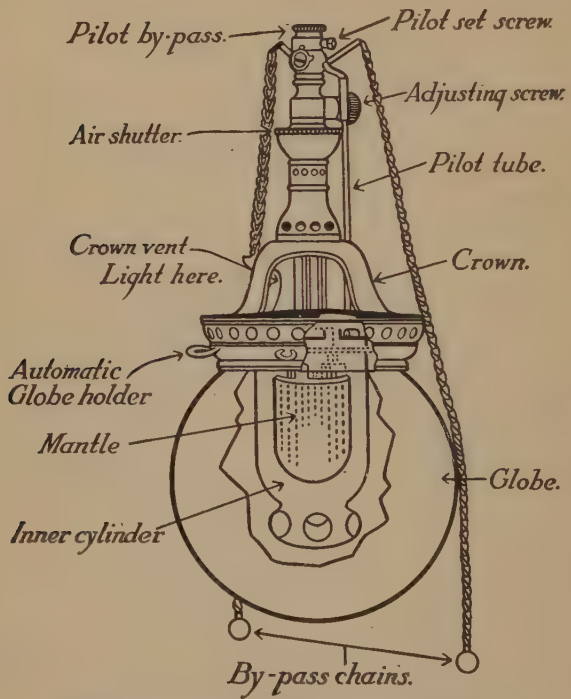
Problem 2 — How a gas lamp burns

Class Problem. — Clamp a gas lamp, without the mantle, to a ring stand support. Connect the lamp to the gas pipe with a piece of rubber tubing.

Open the gas cock. Light the gas at the top of the burner. What is the shape of the flame? What color is it? Where

does this flame get the air it needs to burn? What makes the flame blue? Does a blue flame give as much light as a yellow flame? Then why is a blue flame used on a gas lamp?

How the chain pulls work. Pull the chain that puts out the light. Explain why the light goes out. Notice the



This shows all the parts of an inverted gas lamp

pilot flame. Why does this continue to burn? Pull the other chain. What does this chain do? Explain.

The pilot flame. What is the pilot flame for? Why does it keep burning when you turn off the light? Why is the pilot flame so small? Notice the pilot regulating screw.

With a small screw driver turn this screw in and out. Watch the pilot flame. Why does it change in size? Adjust the pilot flame until it is about an eighth of an inch high.

The gas regulating screw. Turn on the gas and ignite it at the top of the burner. With a small screw driver turn the gas regulating screw in. Watch the flame. Why does it grow smaller? Turn the screw out. What happens to the flame? Explain how the gas regulating screw makes the flame larger or smaller.

The air shutter. Ignite the gas at the top of the burner. Turn the air shutter so that the air ports are wide open. Hold a smoking wooden splint close to the air ports. Where does the smoke go? What does this prove? This is called *primary air.* What happens in the mixing tube? Does this mixture contain more gas or more air? From what other source does the burning gas at the top of the burner get air? This is called *secondary air.* Turn the air shutter so that the air ports are closed. How does the flame change in color? What is the reason for this change? Does the burning gas get any primary air? Where does it get the air it needs to burn? Hold a white plate in the yellow flame. What happens? Where does the carbon come from? Why is this flame yellow? Open the air ports again. Why does the color of the flame change to blue? Hold a white plate in the blue flame. Examine it. Do you find any carbon? How do you account for this? Which is hotter, a blue flame or a yellow flame? Why is a blue flame used on a mantle gas lamp?

Problem 3 — How a gas lamp gives light

Use upright incandescent gas lamps. The Junior Welsbach and the C. E. Z. are the best types to study. C. E. Z. mantles are soft when you buy them. The fabric has not

been burned out. Directions for burning out the fabric come with these mantles.

Class Problem. — Examine a gas mantle. What shape is it? Describe the fabric. How is the mantle woven? Why is it called a Welsbach mantle? What are *thorium* and *cerium?* Why are mantles dipped into solutions of these salts? What is left after the fabric is burned out of a mantle? Why does a mantle break so easily?

Clamp a gas lamp to a ring stand support and connect it to the gas pipe with rubber tubing. Put on the mantle, taking care not to break it. Touch the bottom of the mantle with the flame of a match, to burn off the paraffin. Why are these mantles dipped into melted paraffin? (If you use a C. E. Z. gas lamp, first blow through the mantles and then hang them on the burner tips. Now turn on the gas and light the mantles. Let them burn for several minutes.)

Lighting a Junior Welsbach burner

Light the mantle. What is the proper way to do this? Why do you wait a moment before applying the burning match? Why do you hold the match above the mantle? Describe the light of the mantle. Where is the blue flame? What does the blue flame do? Why is a blue flame used?

Hold a piece of iron wire in the blue flame of a Bunsen burner until it becomes red hot. Remove the iron wire from the flame. Why does it give light? Would a mantle

made of fine iron wire give light? What objection is there to using gas mantles made of iron wire? How do you account for the remarkable brilliancy of the Welsbach mantle? Why are cerium and thorium used? What is *incandescence?* What is the purpose of making the fabric of these mantles so thin?

Problem 4 — How to adjust a gas lamp

Class Problem. — Set up a gas lamp as directed in the previous problem. Open the gas cock and light the mantle.

How to adjust the pilot. Pull the chain to extinguish the mantle. Examine the pilot flame. With a small screw driver, turn out the pilot regulating screw. Why does the pilot flame become larger? A large pilot flame frequently cracks the glassware and globes of gas lamps. How do you account for this? Turn the pilot regulating screw in until the pilot flame is about an eighth of an inch long. This is the proper length. Why is a large pilot flame expensive?

How to adjust the air shutter. Turn the air shutter so that the air ports are wide open. If the lamp " back fires " or " roars," partly close the air shutter. Why do some gas lamps give off carbon? How can you remedy this trouble?

How to adjust the mantle flame. Light the mantle. Turn the gas regulating screw in. Why does the mantle become dim? Turn the gas regulating screw out until the mantle is bright. Now continue to turn this screw. *Why doesn't the mantle become brighter?* Does a mantle give any more light when you use a " lot " of gas? How do you account for this?

To adjust the mantle flame properly proceed as follows: Light the mantle. Turn down the gas regulating screw until the light of the mantle becomes dim. Now turn the

regulating screw out, until further opening produces no increase in the amount of light given out. Next turn down the screw until the amount of light begins to diminish. The lamp is now regulated. Is the mantle bright over the entire surface? Can you see any flame above the mantle? What would this show? What effect would this flame have on the chimney and shade of the lamp? Why does it cost less to use a gas lamp when it is properly adjusted? Why do the mantles and shades last longer?

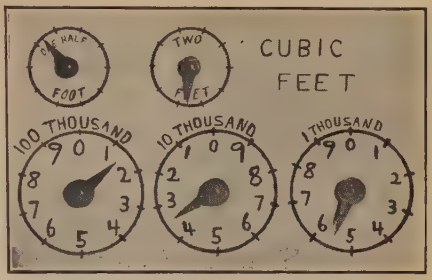
Turn the screw to adjust the gas

Home Problem. — Do you use gas lamps at home? Inspect these lamps to see if they are properly adjusted. Can you see any flames above the mantles? Do you buy cheap mantles? Do the mantles of your gas lamps give a good light? How long do they last? What troubles have you ever experienced with gas lamps? Can you remedy any of them?

Problem 5 — How gas is measured

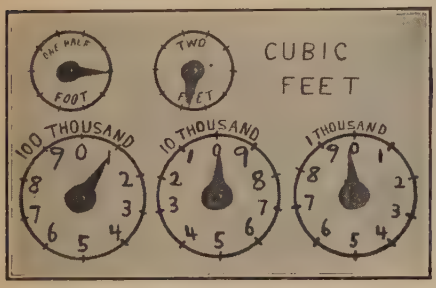
Home Problem. — Locate the gas meter at home. Notice the dial. How many circles do you find? How many cubic feet of gas are registered by each circle? Into how many divisions is each circle divided? In what direction does the hand of each circle turn? *Read your meter.* How many cubic feet of gas does it register?

Class Problem. — Rules for reading a gas meter. Read the three large circles, the 1000 foot circle, the 10,000 foot circle, and the 100,000 foot circle. Notice that each circle is divided into ten equal divisions. One division of the 1000 foot circle equals 100 cubic feet. One division of the 10,000 foot circle equals 1000 cubic feet. One division of the 100,000 foot circle equals 10,000 cubic feet. Notice the three hands. The hand of the 1000 foot circle turns to the right. The hand of the 10,000 foot circle turns to the left. The hand of the 100,000 foot circle turns to the right. All three hands move at the same time when gas passes through the meter. The hand of the 1000 foot circle moves ten times as fast as the hand of the 10,000 foot circle, and one hundred times as fast as the hand of the 100,000 foot circle. When the hand of the 1000 foot circle makes ten complete revolutions, the hand of the 10,000 foot circle makes one complete revolution, while the hand of the 100,000 foot circle moves one division.



This reading is 13,500 cubic feet

Make a board like this for practice reading

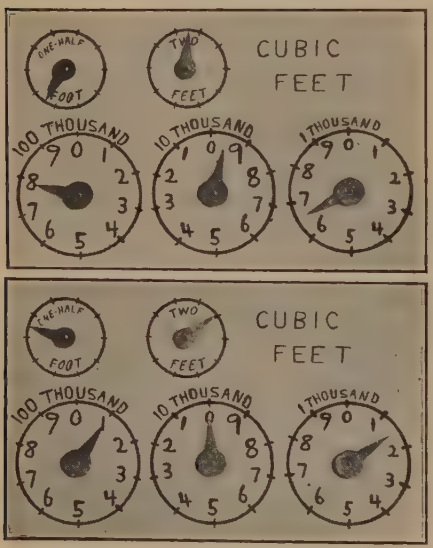


This reading is 9,900 cubic feet

Read the 1000 foot circle first. Does the hand turn to the right or left? What is the last number this hand

passed by? Read the middle circle. In what direction does this hand turn? What is the last number this hand passed by? Read the 100,000 foot circle. Does the hand turn to the right or left? What is the last number this hand passed by? What is the total reading? Why do you add two ciphers?

When the hand of a circle seems to point directly at a number, look at the hand of the preceding circle. If the hand of the preceding circle has passed zero, read the larger number. If the hand of the preceding circle has not reached zero, read the smaller number.



Read the following dials for practice.

Read the gas meter at home. Make a neat drawing to show the circles and the exact position of each hand.

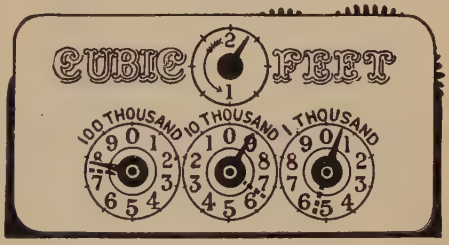
Read the meter again at the end of seven days. Estimate the cost of gas in your home for one week. Write out your report in the form of a bill.

Problem 6 — The cost of gas

Home Problem. — (a) Find an old gas bill at home. What is the cost per 1000 cubic feet? How many readings did the gas company take of your gas meter? When were these readings taken? Why were the two readings subtracted? How many cubic feet of gas did you use? Is

there a quarter prepayment meter in your house? How many cubic feet of gas should you get for a quarter? When you drop in the next quarter, read the meter. Read the meter again when you have used up this allotment of gas.

(*b*) *How a gas bill is made out.* Meters are usually read once a month. The reading of the previous month is subtracted from the reading of the next month. Let the dotted lines represent the position of the hands on May first. Let the unbroken lines represent the position of the hands on June first.



Latest reading (June 1) = 79,000 cubic feet
Previous reading (May 1) = 76,500 cubic feet
Consumption of gas = 2500 cubic feet
Rate = $1.00 per 1000 cubic feet
Amount of bill = $2.50

PROJECT IV

HOW WE LIGHT OUR HOMES WITH ELECTRICITY

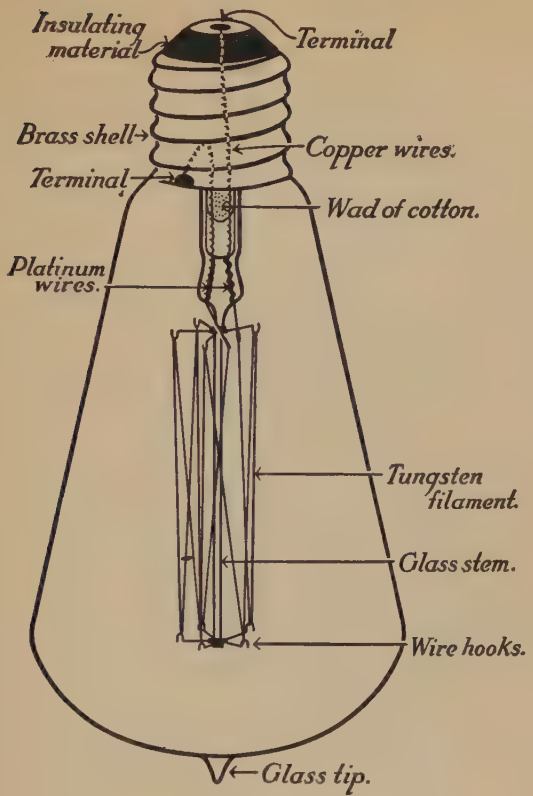
Problems — 1. How an electric lamp is made.
2. How an electric lamp gives light.
3. How an electric lamp burns out.
4. How our homes are wired for electricity.
5. How electricity is sold.
6. The cost of electricity.

Problem 1 — How an electric lamp is made

Home Problem. — Screw an electric lamp out of a socket and study it. Locate the following parts.

1. Glass disk at base
2. Ring of black material
3. Brass shell
4. Lead solder
5. Copper wires
6. Wad of cotton
7. Glass stem
8. Platinum wires
9. Copper terminals
10. Wire hooks
11. Tungsten filament
12. Glass tip

Class Problem. — Take a Mazda electric lamp. Examine the base of this lamp. What is the ring of black material? What is the purpose of the brass shell? Notice the solder. What is this for? Locate the two copper wires leading from the base up through the glass tube. Where are these wires attached at the base? Why are they separated by a wad of cotton? Notice where these two wires pass through the solid glass stem. Why are these parts made of platinum? Locate the fine tungsten wire inside the lamp. Why is this wire supported by little hooks? Trace the tungsten filament from one terminal to the other. Why is the filament inclosed in a glass bulb? What is the glass knob at the tip of the lamp?



An electric bulb

Problem 2 — How an electric lamp gives light

Home Problem. — Light an electric lamp at home and examine it closely. What part of this lamp gives light? Describe the filament. What is it made of? What is tungsten? Place one hand on the outside of the bulb. How does it feel? Where does this heat come from? What heats the tungsten filament inside the lamp? Will a piece of iron wire give light if you heat it red hot? White

hot? Will it give as bright a light as the tungsten wire in an electric bulb? Which glows more brightly when heated white hot, tungsten wire or iron wire?

Snap the switch quickly. Turn the light on and off several times. Watch the filament. Why does an electric lamp "go out"? Does it go out at once? Explain why the filament glows for a moment after the electricity is "turned off." Why does the filament cool so quickly? Which stays hot longer, a thick piece of iron or a thin piece? A thick tungsten filament or a thin tungsten filament? Why do some electric bulbs "go out" quicker than others? Explain why some bulbs give more light than others.

Problem 3 — How an electric lamp burns out

Home Problem. — Examine a "burned out" lamp at home. Will this lamp give any light? Notice the tungsten filament. What happened to this filament when the lamp burned out? Can electricity pass through the broken filament? Break a "burned out" electric bulb, by throwing it on the basement floor. Carefully sweep up all pieces of glass. What happens when the bulb breaks? What causes the noise? This is not an *explosion.* The glass sides of the bulb simply "cave in." How can this happen?

Class Problem. — (a) Fill a large glass jar with water. Hold the glass tip of a bulb under water, and keep it there. With a pair of pliers break off the glass tip. What happens? How do you explain this? What makes the bulb fill with water? What is a vacuum? Why is the air removed from an electric bulb? Take the bulb out of the water, and hold it erect with the broken tip up. Notice whether the bulb is entirely filled with water. What is the bubble left in the bulb? What is a perfect vacuum? Why does

an electric lamp filament "burn out" after it has been used for some time? What gas in air helps things to burn? Why would the filament burn longer if all the air could be removed from the bulb? Some bulbs are filled with a gas called nitrogen, which neither burns nor helps other things to burn.

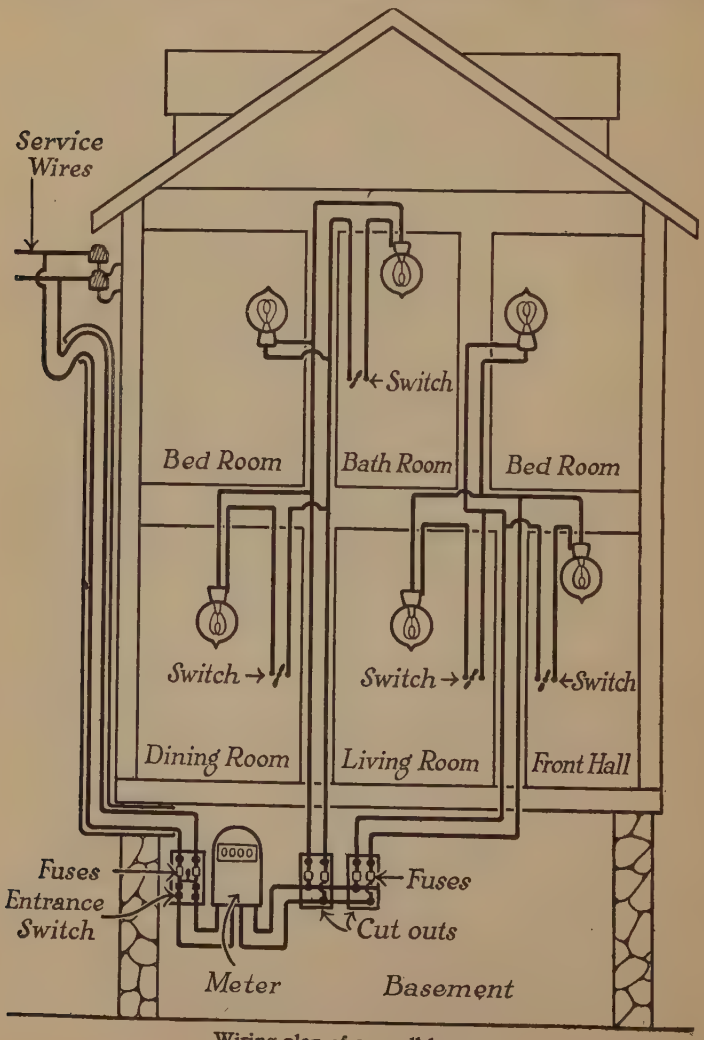
Keep the tip of the bulb under water as you break it

(*b*) *Light an electric lamp.* With a pair of pliers break off the tip at the end of the glass bulb. *What happens?* What is the hissing sound? Why does the light go out? Screw the lamp out of its socket and examine the tungsten filament. What happened to this filament when air rushed into the glass bulb? Can the filament burn in a vacuum? Can it burn in a bulb filled with nitrogen?

Problem 4 — How our homes are wired for electricity

Home Problem. — Do you use electricity at home for lighting? Study the wiring plan on page 244. Where does the electricity come into the house? How many wires are used? Why are two wires necessary? Where do these wires come from? Why do they pass through an iron

pipe? How do the electric wires come into your own house? Notice the entrance switch. What happens when you open the switch? When you close it? Locate the



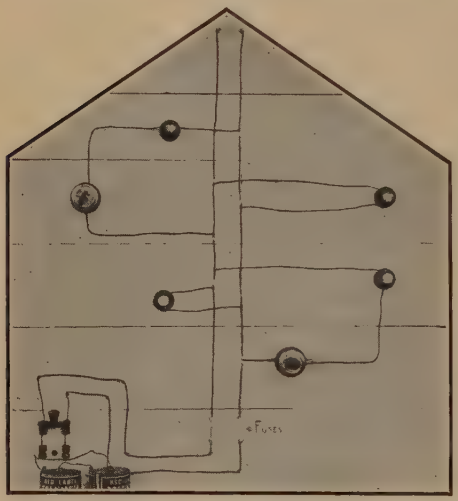
Wiring plan of a small house

entrance switch in your own house. Describe it. How does it work? Notice the meter. What is this for? How do you buy electricity? Have you an electric meter in your house? Where is it? Describe it. How does it measure the amount of electricity used? Notice the fuse block with the two fuses in the wiring plan.

Examine an electric fuse. How is it made? Break open a fuse with a hammer. Take out the short piece of wire. Hold this wire, with pliers, in the gas flame for a few moments. What happens? How do fuses protect your house? Why do fuses "burn out"? Examine a "burnt out" fuse. What happened to it? Why do the electric lights go out when a fuse "burns out"? How do you put in a new fuse? *Notice how the switches and lamps are connected in the wiring plan.* What are electric switches for? How do they work? Have you any electric switches at home? What happens when you press the button? Why do the electric lamps go out? Why do they "light up" again? Screw an electric bulb out of its socket. *Don't put your fingers inside the socket.* Why? Look closely at the interior of the socket. How does the electricity pass from the socket into the bulb? Make a drawing to show how your house is wired for electricity. Label all parts neatly.

Class Problem. — Make a demonstration wiring board two and a half feet wide and three feet high. Let this board represent a house. With chalk, mark off the board in sections to represent the basement and four rooms. Wire this house, as shown in the illustration, using two single pole snap switches, four miniature lamp receptacles, four miniature lamps, a single throw knife switch, and ordinary bell wire. Fasten the receptacles and switches to the board with small screws.

For a fuse block, drive four small nails into the board about an inch apart in the form of a square. Connect these nails, as shown, with pieces of tin foil, such as comes around candy or yeast cakes. Connect two dry cells from carbon to zinc. Attach the wires from these cells to the model house circuit, as shown in the illustration. Do the work neatly. Make all connections tight. Turn on the lights.



Wire a board like this with miniature lamps

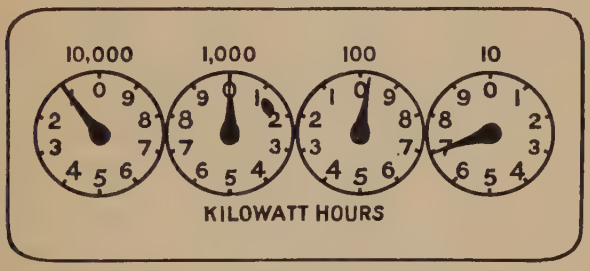
How does electricity flow from the dry cells to each lamp? Starting with one wire, trace the complete circuit for each lamp. Open the knife switch. Why do the lights go out? Close the knife switch. The pieces of tin foil, connecting the nails, represent fuses. Heat one of these pieces of tin foil with a match flame. *What happens?* Why does the tin foil melt? Why do the lights go out? The wires in real fuses are also made of metals which melt at a low temperature. Why do they " burn out " ?

Connect the two nails with a new piece of tin foil. Snap one of the switches " on " and " off." What happens? Screw off the thumb piece and remove the cover from this switch. Screw the thumb piece on again. Now snap the switch " on " and " off." Explain how the switch works. How does it light the electric bulb? How does it put out

the light? Examine the lamp receptacles. How are they connected? How does electricity pass from these receptacles into the lamps? Make a drawing of this wiring plan. Label all parts neatly.

Problem 5 — How electricity is sold

Electricity is measured and sold by what is called the kilowatt hour. A kilowatt is equal to 1000 watts. Let us assume that a kilowatt hour costs 15 cents. Then you can use 1000 watts of electricity for one hour for 15 cents. If



Dial of electric meter. This reading is 997 kilowatt hours

you use 1000 watts for 2 hours, it will cost 30 cents. 100 watts for one hour will cost $1\frac{1}{2}$ cents. Examine the paper label on the outside of an electric bulb. You may find 25 W, 40 W, 50 W, or 100 W, etc. Now W stands for watts. If 100 W is printed on the label, the bulb uses 100 watts of electricity, and it costs $1\frac{1}{2}$ cents per hour. At the same rate, a 50-watt bulb will cost only $\frac{3}{4}$ of a cent per hour.

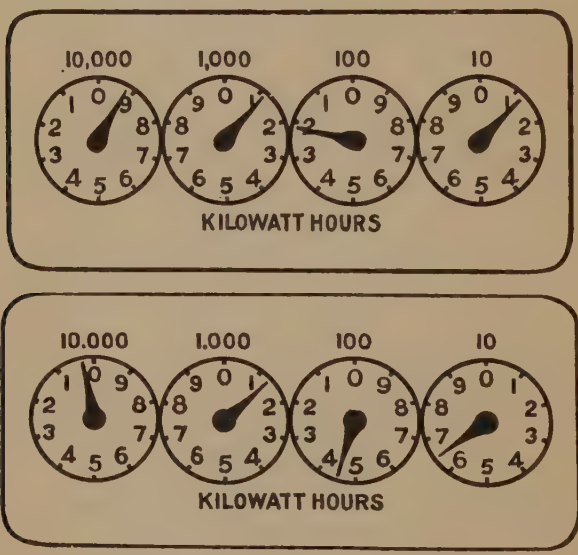
Home Problem. — (*a*) *Examine the labels on electric bulbs at home.* Find out how much you pay per kilowatt hour for electricity. Determine the cost per hour of each of these bulbs. Arrange your results neatly in a table.

(*b*) *Locate the electric meter at home.* How many circles do you find? How many kilowatt hours are registered by

each circle? Into how many divisions is each circle divided? In what direction does the pointer of each circle turn? *Read your electric meter.* Make a drawing of the circles to show the position of each pointer.

An electric meter is read exactly the same as a gas meter. See Problem 5, page 237. Usually there are four circles. The lowest circle registers 10 kilowatt hours, and the highest circle 10,000 kilowatt hours. Read the 10 kilowatt hour circle first.

Read the following dials for practice.

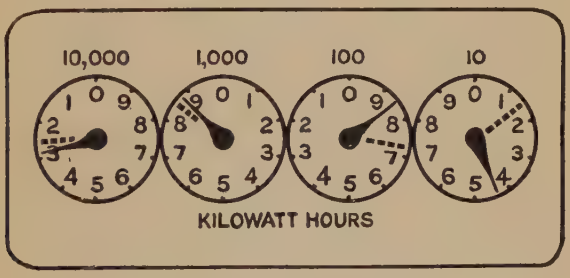


Problem 6 — The cost of electricity

Find an old bill for electricity at home. What is the cost per kilowatt hour? How many readings did the Electric Company take of your meter? When were these readings taken? What was the date of the previous reading? The latest reading? Why are these two readings subtracted?

How many kilowatt hours of electricity did you use? What is the amount of the bill?

How a bill for electricity is made out. Meters are usually read once a month. The reading of the previous month is subtracted from the reading of the next month. Let the dotted lines represent the positions of the pointers on April first. Let the unbroken lines represent the positions of the pointers on May first.



KILOWATT HOURS

Latest reading (May 1) = 2884 kilowatt hours
Previous reading (April 1) = 2871 kilowatt hours
Amount of electricity used = 13 kilowatt hours
Rate = 14 ¢ per kilowatt hour
Amount of bill = $1.82

FACTS EVERY ONE SHOULD KNOW ABOUT LIGHTING

Light and Temperature. — A piece of cold iron gives no light, but when you heat it, this iron at first shows a dull red, then a bright red, and finally a brilliant white. The iron gives more and more light as the temperature is raised. In the same way the light of a candle flame is due to glowing particles of red-hot carbon, the dazzling light of a gas lamp to the high temperature of the mantle, and the brilliance of a Mazda to the white-hot tungsten filament.

Transparency. — When light rays strike any substance, one or all of three things may happen to them. They may pass right through the substance. Secondly, they may strike the substance and bounce back again. In the third place, these light rays may be absorbed by the substance. Light passes through air, water, and glass. Such substances are called transparent. This explains why we have glass windows in our homes and glass chimneys on our lamps. Sometimes we pull down the shades to shut out the sunlight. If these shades are made of a dark, heavy material, they may be opaque. They shut out all the light. If the shades are made of a thin material, they may be translucent. Part of the sunlight passes through. Lamp shades, globes, electric light bulbs, and window panes are frequently made of frosted or ribbed glass, which is translucent. This glass dims or softens the light. When you try to look through it, objects are not clearly visible. They appear indistinct and blurred.

Reflection. — When light rays strike some substances they bounce back again, like a rubber ball. This is called reflection. If you stand in a sunny window and let the sun's rays strike the surface of a mirror, a bright spot of light appears on the ceiling. Tip the mirror forward and

back. The bright spot on the ceiling moves forward and back. Tip the mirror sideways. The bright spot moves sideways. To understand this peculiar behavior of light, take a rubber ball and bounce it on the kitchen floor. Throw the ball straight down. It bounces straight up again. Throw the ball on a " slant." It bounces away from you on the same " slant." Rays of light act in the same manner. They are always reflected from a surface at the same " slant " or angle at which they strike it. The reflectors of automobile headlights are shaped so that the rays are all thrown forward, to light the road ahead. Perhaps you have noticed the concave reflectors of lamps or pocket flash lights. They are made concave in shape to throw rays forward in a narrow stream of bright light.

When light strikes an object with a smooth, polished surface, many of the rays are reflected in the same direction and the object appears shiny. Reflectors are made of highly polished metals. You rub your shoes with a rag to make the leather smooth and shiny. When light strikes an object with a rough surface, the rays are scattered or reflected in many different directions and the object appears dull. This explains why such objects as rusty iron, muddy shoes, dirty faucets, rugs, blotting paper, and rough boards are dull.

Reflection plays an important part in your lives and mine, because we see things by reflected light. The print on this page is made visible to you because some of the light rays that strike the page are reflected, and pass through the openings in your eyes, forming a picture of the words on the delicate membranes at the back. You may have wondered how sunlight can pass through thick clouds or come into the windows on the shady side of your house. These rays of light are thrown back and forth thousands of times

by countless particles of dust and tiny drops of water floating in the air. The light is reflected again and again until it passes from some object into your eyes and makes this object visible.

Have you ever watched a searchlight at night send a straight beam of light across the sky? When light passes through the same substance it travels in straight lines. Hold one hand between a lighted lamp and the wall. A shadow appears on the wall. This shadow is formed because the rays of light from the lamp travel in straight lines. They cannot pass around your hand to "light up" the space directly back of it.

Refraction. — When light passes from one substance into another, as from air to water, or from air to glass, the rays are bent. A stick partly submerged in the water appears bent or broken at the surface. The part under water seems to bend upward. A pond is always deeper than it seems to be. You can start a fire by letting sunlight pass through a piece of glass with rounded sides. Simply hold a sheet of paper back of the glass and move it back and forth, until a small spot of bright light appears on the paper. Hold the paper still for a few moments and it may start to burn. This piece of glass is called a *lens*. When light passes through the glass, the rays are bent and come together at a point called the *focus*. If you hold a lens between a burning candle and a sheet of paper, and move the paper forward and back, an image of the candle will be formed on the paper. This explains why glass lenses are used in cameras, microscopes, telescopes, and eye glasses. These lenses are of many different shapes and thicknesses. Some have hollow sides while others have bulging sides. Some are thick and others are thin. The images formed by different lenses may be of different sizes and at different distances.

The lenses of the microscope form an image that may be more than a thousand times as large as the object. This makes it possible for us to see extremely small objects, such as bacteria, which are invisible to the naked eye. The human eye is built like a camera. Just back of the little opening called the pupil is a crystalline lens. Light rays that are reflected from an object pass through this lens, and an image is formed on a delicate membrane at the back of the eye, called the retina.

Artificial Lights. — During the day we usually receive enough light from the sun. At night, however, we are compelled to use artificial lights. We are especially fortunate to-day, because we can make our homes and streets almost as bright as day with gas mantles and electric lamps. Our ancestors had only the feeble, flickering light of tallow candles to see by at night. Most of the candles that we use to-day, on special occasions, are made of paraffin. You have watched a candle burn. Heat from the flame first changes solid paraffin to a liquid. This liquid passes up through the tiny holes in the wick and is then changed, by heat, into different gases. A candle flame is made up of two distinct parts, a dark central cone and a bright outer cone. The dark cone in the center of the flame is composed of gases which have just been formed. These gases do not burn in the dark central cone for two reasons. In the first place they have not received sufficient heat to raise them to the kindling temperature; and secondly, the oxygen needed for combustion is lacking. The bright outer cone is composed of burning gases. Paraffin is composed of two familiar elements: carbon and hydrogen. When a candle burns, the carbon combines with oxygen to form carbon dioxide. Hydrogen combines with oxygen to form water. The light of a candle flame is due to millions

of tiny particles of red-hot carbon which glow for an instant before they burn up.

Lamps. — Lamps are older than candles. They have been used for hundreds of years. Some of the earliest lamps, such as were used by the ancient Greeks and Romans, are very crude. They consist of a shallow bowl, partly filled with oil or grease, in which a wick is laid. These old lamps burned with smoky, feeble, flickering flames, so that it was almost impossible to read by them. Our grandparents filled their lamps with whale oil. In 1858, when petroleum was discovered, kerosene became the popular fuel for lamps.

Kerosene lamps are common to-day, especially in country homes. They are manufactured in many designs and patterns, some with circular wicks and a central draft, others with flat wicks and a chimney draft. Common kerosene lamps burn with a yellow flame. Kerosene passes from the reservoir up through the tiny holes in the wick, and is changed into different gases by the heat. These gases burn at the top of the wick with a yellow flame. Kerosene, like paraffin, is composed of carbon and hydrogen.

A lamp needs plenty of air to burn properly. This air passes in through the holes at the base, or under the burner. The draft in a lamp is similar to the draft in a stove. The flame heats the air inside the chimney. This air expands and consequently weighs less than the outside air. Hence, cold, heavier air flows into the chimney and pushes the warm air up. If you turn the wick up too high the flame smokes and unburned carbon collects on the inside of the chimney. This is caused by lack of oxygen. You are trying to burn too much kerosene at once. Some of the carbon passes off unburned because it has no oxygen to unite with. Kerosene lamps, especially those with central drafts and circular

wicks, give a soft, bright, steady light. If you use lamps for lighting take good care of them. Keep the chimneys bright and clean. Trim the wicks, evenly, at least once a week. Fill them every day before you light them. Wipe the soot off the burners and keep the little holes open, so that the lamps will receive plenty of oxygen.

Gas Lamps. — Gas lamps are used in many homes to-day for lighting. There are two types of gas lamps in common use: those with open flames and those with mantles. Open flame gas lamps are extremely wasteful and expensive. Gas comes out through a narrow slit or through little holes at the top of a small brass tube and burns with a flat yellow flame. This flame uses much more gas than a mantle and gives less light. The mantle gas lamp is really a Bunsen burner. Air is mixed with gas before it burns. This comes in through port holes near the base of the burner. The flame of a mantle gas lamp is blue. It produces very little light, but much heat. It is the same flame that you use on your gas stove for cooking. When a Welsbach mantle is hung over this blue flame, it becomes white hot and glows, producing a light of remarkable brilliance. Gas mantles are usually made of artificial silk. They are woven into little bags and then dipped into a solution of two rare chemical substances called thorium and cerium. The silk fiber is next burned out; only the salts and ashes remain. For this reason a gas mantle is extremely fragile. It breaks very easily. It is dipped into melted paraffin for shipping. When you put on a new mantle, you always burn off this paraffin before you light it. The silk fiber of some mantles is not burned out in the factory. These mantles are soft when you buy them. You have to burn out the silk fiber yourself. Perhaps you have wondered why a gas mantle gives such a brilliant light. If a mantle made of fine iron wires

is hung over the blue flame of a Bunsen burner it becomes white hot and gives light, but the light has not the brilliance of the Welsbach mantle. When some substances are heated they glow more brightly than others. Scientists hunted for many years and tried many substances until they found the rare elements, thorium and cerium. Compounds of these elements, when heated to a high temperature, produce the wonderful brilliance of the Welsbach mantle. Gas lamps should be adjusted occasionally. Keep the port holes open. Adjust the gas regulator as directed. No flame should appear above the mantle. The pilot flame should not be over an eighth of an inch long. A large pilot flame wastes gas and cracks the glass shades.

Some people believe that the brilliance of a gas mantle depends on the quantity of gas burned. This is not true. Use only enough gas to heat the mantle white hot. You can't make it any hotter, no matter how much gas you use. Sometimes a gas lamp "pops" or makes a "roaring" sound. This is a sign of too much air. You can remedy this trouble by partly closing the air shutter. If mantle gas lamps are properly adjusted they give a light of remarkable brilliance at a comparatively low cost. Learn how to read your gas meter. Check up your bills each month. Protect yourself against mistakes or carelessness.

Electric Light. — In many homes to-day electricity is used for lighting. You have examined an electric bulb. This is one of the greatest inventions of modern times. We are indebted to the famous inventor, Thomas Edison, for this remarkable light. Mr. Edison worked for many years and spent hundreds of thousands of dollars to perfect the electric bulb. He succeeded in putting a carbon filament, made of bamboo fiber, into a glass bulb. He then pumped the air out of this bulb and sealed it at the top. His un-

tiring efforts were finally rewarded. When a current of electricity was passed through the bulb, the carbon filament was heated white hot and gave off a bright light. The first electric bulb was patented in 1880. Since then, many improvements have been made. The rare metal, tungsten, has replaced carbon for filaments. If you examine a bulb, you will see the delicate, hairlike tungsten wire inside, suspended by little hooks. Now electricity heats some materials more than it does others when it passes through them. We say that these materials have a higher *resistance.* Perhaps you have noticed how quickly the wires of an electric bread toaster become hot. These wires are made of materials which have a high resistance. Tungsten has an extremely high resistance. For this reason, the tungsten filament in a bulb is heated white hot when electricity passes through it. If you hold the end of a bulb under water and break off the glass tip, water rushes in like a fountain. This experiment shows that there is a vacuum inside the bulb. The air has been pumped out. If bulbs contained air, the oxygen would burn up the tungsten filament at once. It is almost impossible to remove all the air from a bulb. A little air remains. It is the oxygen in this air that slowly burns up the filament and the bulb "burns out." Some bulbs are filled with a gas called nitrogen. This gas will not burn, nor will it help anything else to burn. The filaments of these lamps usually last a long time.

Notice the paper label stuck on the outside of an electric bulb. This label tells you how much electricity the bulb uses. This makes it possible for you to estimate very easily how much it costs to use electrical appliances, such as bulbs, motors, bread toasters, flat irons, and stoves. All you need to know is the cost per kilowatt hour, and the number of watts each appliance uses.

There are several methods of lighting in common use to-day. In *direct lighting*, opaque or translucent reflectors are suspended just above the lamps. These throw most of the light down and "light up" a limited area very brightly. In *indirect lighting*, opaque reflectors are suspended just under the lamp. All the light is first thrown up to the ceiling and then it is again reflected to different parts of the room. This system of lighting gives a soft, pleasant light, which is restful to the eyes. It is expensive, however, for much of the light is wasted. In *semi-indirect lighting*, translucent reflectors are suspended just under the lamps. Part of the light comes through the reflector while part of it is thrown upward to the ceiling and is again reflected. This system is more economical than indirect lighting, but it costs more than direct lighting.

The most important thing to remember about lighting is the effect it has on your eyes. A dim, feeble light strains the eyes. A light of intense brilliancy is even worse. This produces a glare that hurts the eyes. A soft, steady light, that illumines objects clearly but without glare, is the best. Some people face the light when they read. They let it shine directly into their eyes. This is extremely harmful. Sit back to the light when you read. Let the light fall on your book. Remember that you see things by reflected light.

CHAPTER VIII

ELECTRICITY IN OUR HOMES

NOBODY ever saw electricity. Nobody even knows what it really is. It seems as mysterious in these respects as it was twenty-five hundred years ago, when the Greeks picked up bits of paper by rubbing a piece of amber. And yet we know how to make electricity; we can change it from one form to another; or we can store it away for future use. With its help we can send messages over wires, or even through the air, for thousands of miles.

We know electricity by what it does. We recognize it in the ring of the electric bell, in the firing of the gasoline engine, in the spark of the wireless, in the red-hot wires of the bread toaster, in the "whirr" of the electric motor, in the brilliant glow of the Mazda bulb, in the penetrating light of the X-ray, or in the words that come from a telephone receiver. In these, and many other ways, electricity has come to play a very important part in our daily lives.

In the following chapter we want you to find out some facts about electricity: where electricity comes from, how magnets act, how electric bells ring, how messages are sent by telegraph, how electric motors run, how we plate things with electricity, how electricity is stored, and how heat is produced by electricity.

PROJECT I

WHERE ELECTRICITY COMES FROM

Problems — 1. How electricity comes from rubbing.
2. The electric cell and how it works.
3. How to set up a wet cell
4. How a dry cell works.

Problem 1 — How electricity comes from rubbing

Home Problem. — Tear a piece of paper into small bits. Rub a fountain pen briskly on your coat sleeve. Touch

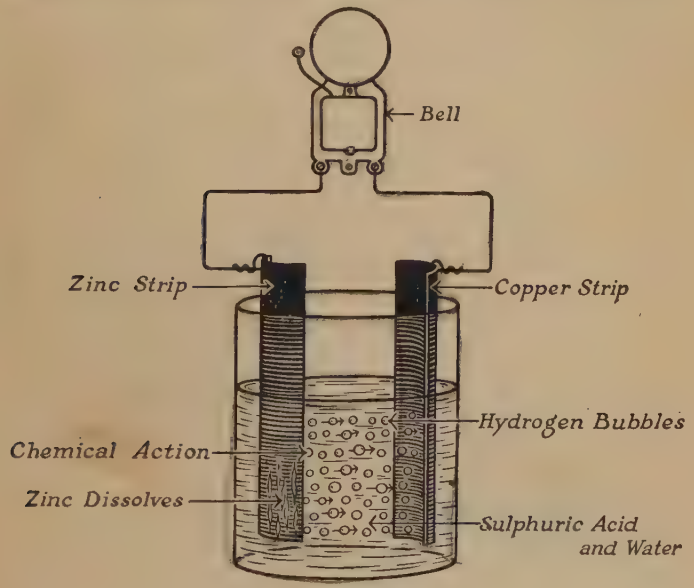
How large a piece of paper can you pick up with a comb?

the bits of paper with the end of the fountain pen. Repeat several times. How many bits of paper can you pick up? Rub the back of a rubber comb briskly on a flannel rag. Pick up pieces of paper. Hold the comb close to a water faucet or radiator. Can you see a tiny spark of electricity? What happens when your mother combs her

hair briskly with a rubber comb? What is the "crackling" noise? Why do strands of hair follow the comb? Rub the fur of a cat's back vigorously. What is the "crackling" noise? Rub the cat's fur with a rubber comb. Pick up pieces of paper. Hold the comb close to a radiator or iron pipe. What is the tiny spark?

Problem 2 — The electric cell and how it works

Class Problem. — Take a strip of sheet zinc, five inches long and four inches wide, and a strip of copper of the same



An acid cell

size. Punch a hole in each metal strip near the top. Cut off two pieces of copper wire, about two feet long. Slip an end of one piece of wire through the hole in the zinc strip and twist it tightly. Attach the second piece of wire to the copper strip in the same way. Fasten the opposite

ends of the wires to the binding posts of a small electric bell. Now lower the metal strips into a glass jar. A quart-size battery jar works well. Pour water into the jar until it is about two-thirds full. Now add concentrated sulphuric acid, a few drops at a time, until numerous bubbles appear. Don't let the metal strips come in contact. *What makes the bell ring?* Where does this electricity come from? Watch the bubbles. Where do they come from? Where do they go?

To find out what these bubbles are, put a few pieces of zinc into a test tube, cover with water, and add sulphuric acid. Hold a match flame just over the mouth of the test tube. What happens? What is this gas? What are the gas bubbles in the cell? Electricity is generated in this cell, and also in other kinds of cells, by *chemical action.*

Problem 3 — How to set up a wet cell

Home Problem. — Does the electricity that rings your door bells at home come from so-called *sal-ammoniac* or wet cells? Examine one of these cells. Describe it. Locate the carbon cylinder; the zinc rod.

Class Problem. — Examine a sal-ammoniac cell, such as is commonly used to ring door bells.

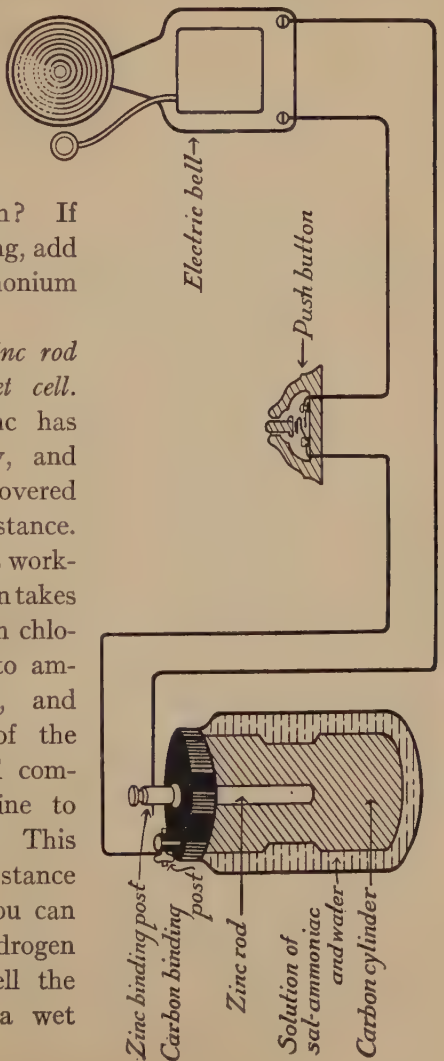
Point out the following parts:

The glass jar	Porcelain insulator
Carbon cylinder	Binding posts
Zinc rod	

Remove the carbon cylinder and zinc rod from the jar. Half fill the jar with cold water. Now fill an ordinary drinking glass with *ammonium chloride.* This is a white crystalline substance commonly called sal-ammoniac. It can be purchased from any hardware store at a few cents per pound. Pour the ammonium chloride into the jar,

and stir constantly. Put back the carbon cylinder and zinc rod. Connect the binding posts of the cell with an electric bell, using two pieces of copper wire. *What makes the bell ring?* Where does this electricity come from? If the bell fails to ring, add a little more ammonium chloride.

Examine the zinc rod from an old wet cell. Some of the zinc has been eaten away, and the rod is partly covered with a white substance. When a wet cell is working, chemical action takes place. Ammonium chloride breaks up into ammonia, hydrogen, and chlorine. Some of the zinc dissolves and combines with chlorine to form zinc chloride. This is the white substance that you see. You can also see the hydrogen bubbles, and smell the ammonia, when a wet cell is working.



A sal-ammoniac cell connected with a push button and bell
Notice how the button completes the circuit when pushed

Connect the wet cell again with an electric bell. Let the bell ring as long as it will. Why does the bell stop ringing? To answer this question, look closely at the surface of the carbon cylinder. Can you see the tiny bubbles of hydrogen clinging to the cylinder? Remove the cylinder from the jar and wipe off these bubbles, both inside and outside. Now put it back into the jar. *The bell rings.* How do you explain this? Why do wet cells need to rest at frequent intervals? What part of a wet cell wears out first? How can you remedy this? Why doesn't the carbon cylinder wear out? What happens to the ammonium chloride in an old dry cell? How can you remedy this?

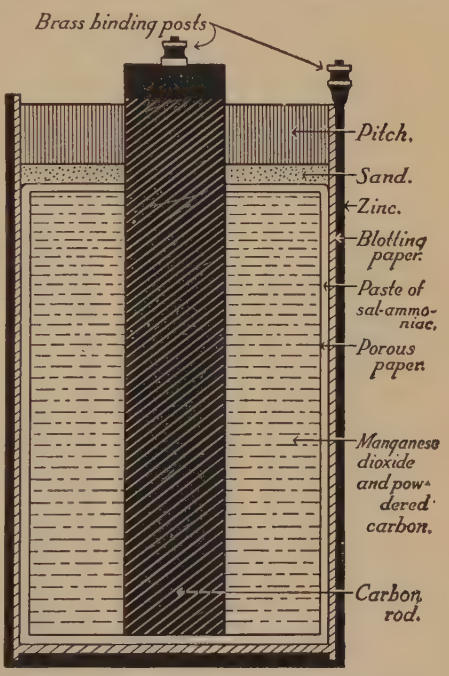
Problem 4 — How a dry cell works

Class Problem. — Take a new dry cell. Ring an electric bell with this cell. Light a small electric bulb, such as comes in pocket flash lights. Does a dry cell "make" electricity?

Study the parts of a worn-out dry cell. First remove the pasteboard box. What is this box for? Can electricity pass through the pasteboard when two dry cells touch each other? *Examine the metal can.* What is this made of? Why is zinc used? Is this zinc partly eaten away? What is the cause of this? *Notice the white salt on the surface of the zinc can.* This salt is *zinc chloride.* How was this last formed? What kind of action do we call this? Why do dry cells wear out? Point out the binding post at the top of the zinc can. What is this for? *Locate the carbon rod.* This rod "collects" the electricity. Does it wear out? Why not?

What is the binding post at the top of the carbon rod for? Electricity passes out of the cell through this binding post. Notice the hard black substance in the top of the

zinc can. It separates the carbon rod from the zinc can. Will electricity pass through rubber? Glass? Wood? Metals? What is an insulator? What is a conductor? Strike the outside of the can, near the top, with a hammer to break up the hard black substance. Take out the pieces. Remove the layer of sand underneath. Sand is used simply as a cheap filling material.



Cut open an old dry cell and compare it with this

Cut open the zinc can with a large knife. Remove the rod of carbon. What is this for? Examine the substance surrounding the carbon rod. Describe it. What color is it? Is it moist or dry? Notice the familiar odor. What causes this odor?

The black substance is a mixture of water, ammonium chloride, powdered carbon, and a black powder called *manganese dioxide.* Why is ammonium chloride used in a dry cell? What happens to the ammonium chloride when a cell "wears out"? Notice the layer of blotting paper next to the zinc. Is this moist or dry? How does ammonium chloride come in contact with the zinc? Does it dissolve in water? Can this

liquid pass through the blotting paper? What happens when the ammonium chloride strikes the zinc can? How is electricity generated? How does this electricity pass across to the carbon rod?

Connect a "worn-out" dry cell with an electric bell. Why doesn't the bell ring? With a nail, punch about a dozen holes through the zinc can. Now set the cell in a pail of water overnight. Remove the following day and connect the cell with an electric bell. What happens? How do you account for this?

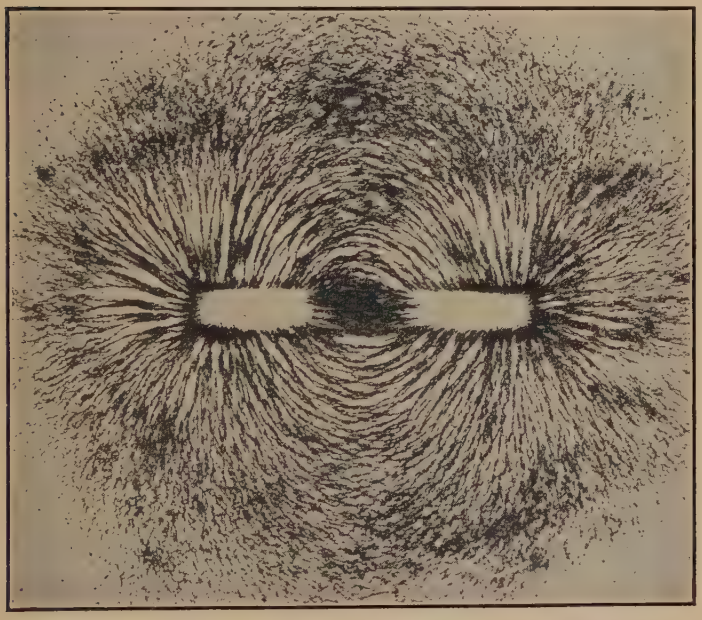
PROJECT II

A STUDY OF MAGNETS

Problems — 1. How a steel magnet acts.
2. How to make a compass.
3. How to make an electro-magnet.

Problem 1 — How a steel magnet acts

Class Problem. — What a magnet does. Take a steel bar magnet. Bring one end of this magnet near the following articles: a silver coin, a nickel coin, a copper coin, a gold ring, a piece of lead, a piece of zinc, a steel pen, a



The iron filings show the lines of force about a magnet. The earth is a big magnet surrounded by similar lines of force

wire nail, a needle. What conclusions do you draw from this experiment?

Examine a bar magnet. What is it made of? How was the bar magnetized? Notice the letter near each end of the steel bar. What does *N* mean? What does *S* mean?

The lines of force about a magnet. Place a bar magnet on the table, and lay a square piece of thin cardboard over it. Sprinkle iron filings evenly over the cardboard, and tap gently. How do the iron filings arrange themselves? Notice carefully how the lines run. What are these lines called? Draw a diagram to show the arrangement of these lines.

The poles of a magnet. Select two bar magnets. Glue strips of paper on both sides of these magnets, near the ends. Print in large type with black ink the letters "*N*" and "*S*." Make a stirrup with stiff wire, and suspend it from a support with a piece of linen thread. Lay one of the bar magnets in the wire stirrup, so that it hangs horizontal. Hold the other bar magnet in one hand and bring the poles near the poles of the suspended magnet, as follows:

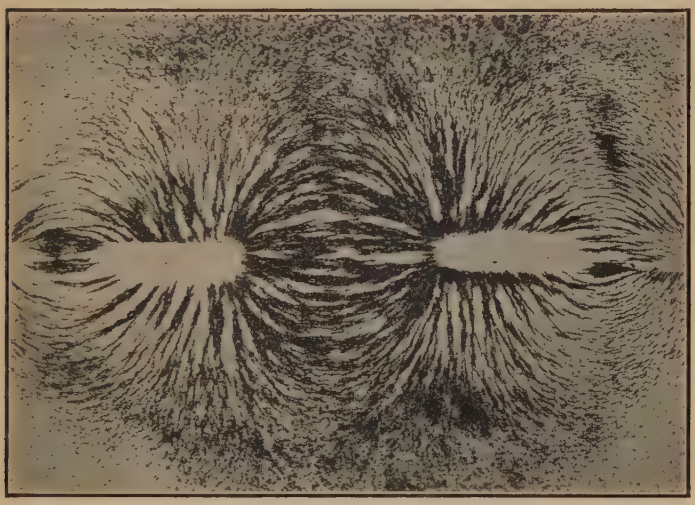
1. Bring a north pole near a north pole.
2. Bring a south pole near a south pole.
3. Bring a south pole near a north pole.
4. Bring a north pole near a south pole.

State the laws of magnets.

1. How do like poles affect each other?
2. How do unlike poles affect each other?

Why do unlike poles attract? Place the two bar magnets on the table, end to end. Have the north pole of one magnet opposite the south pole of the other. The two ends should be about an inch apart. Lay a piece of thin

cardboard over the magnets. Sprinkle iron filings evenly on the cardboard, tapping it a few times with a pencil. How do the iron filings arrange themselves? Draw a diagram to show this arrangement. What do these lines represent? Are the lines themselves visible? Can you



Lines of force between *unlike* poles of two magnets. They try to pull the two magnets together

compare them with tiny elastic bands? What are the lines of force trying to do in this case? Why do unlike poles of magnets attract each other ? Study the pictures. These are photographs showing how iron filings arrange themselves between the poles of magnets.

Why do like poles repel? Place the two bar magnets on the table end to end. Have the north pole of one magnet opposite the north pole of the other. The two ends should be about an inch apart. Lay the piece of cardboard over the magnets as before, and sprinkle iron filings over it. How do the iron filings arrange themselves now? Draw

a diagram to show this arrangement. What do these lines represent? Are the lines themselves visible? What are the lines of force trying to do in this case? Why do like poles of magnets repel each other?

Lines of force between *like* poles of two magnets. They try to push each other away

Problem 2 — How to make a compass

Class Problem. — Secure a large needle, three or four inches in length. With the south pole of a bar magnet, stroke the needle in one direction, from the center to the pointed end. Now, with the north pole of the bar magnet, stroke the needle in one direction from the center to the blunt end. Bring the needle near some iron filings. Try to pick up a steel pen. How have you changed the needle?

Suspend the needle from a wooden support, with a piece of fine silk thread, so that it hangs nearly horizontal. Tap the needle and then let it come to rest. In what direction

does it point? Which end of the needle points north? Which end points south?

Bring the south pole of a bar magnet near the pointed end of the needle. What happens? What does this show? Bring the south pole of the bar magnet near the blunt end of the needle. What happens now? Which pole of the needle of a compass points north? Which pole points south? Why are they called north and south poles?

Examine a small pocket compass. Describe the different parts. What points are shown on the dial of this compass? What is the needle? Which end points north? Does it point true north? Can you state some of the uses of this compass? What is a mariner's compass? What is it used for?

Problem 3 — How to make an electro-magnet

The electro-magnet is an essential part of every dynamo, motor, electric bell, telegraph sounder, and telephone receiver.

What happens when he takes his finger off the button?

Class Problem. — Take a large wire nail, at least five inches long, and a roll of insulated bell wire. Wind three layers of insulated wire around the nail, with close even turns. Fasten the wire by tying a single knot around the nail with each end. Connect the ends of this wire with two dry cells and a push button, as shown in the illustration. The electro-magnet is now ready to use.

Bring one end of this electro-magnet near a steel pen. Press the push button. *What happens?* Release the push button. *What happens?* Why is it called an electro-magnet? Pick up a small nail. A large nail. A pair of scissors. A hammer. Don't press the button longer than a few seconds at a time. You may run down the dry cells. What makes the nail a magnet? Does the nail hold its magnetism after you release the push button?

Why are some electro-magnets stronger than others? Use only one dry cell instead of two. Try to pick up the same articles as before. Unwind two layers of wire from the nail. Leave only one layer. Connect this electro-magnet with two dry cells and the push button. How many articles can you pick up now? How do the number of cells you use affect the strength of an electro-magnet? How is the strength affected by the number of turns of wire used? How would you make a powerful electro-magnet?

PROJECT III

THE ELECTRIC BELL AND HOW IT RINGS

Problems — 1. The parts of an electric bell.
2. How an electric bell rings.
3. How to connect electric bells.

Problem 1 — The parts of an electric bell

Home Problem. — (*a*) Study the diagram of an electric bell on page 274. Note carefully the two coils of the electromagnet, the contact screw, steel armature, spring, binding posts, and wiring plan. How does electricity flow from one binding post to the other?

(*b*) *Locate an electric bell at home.* Remove the iron cover and examine the interior. Make a drawing of this bell and label all parts neatly.

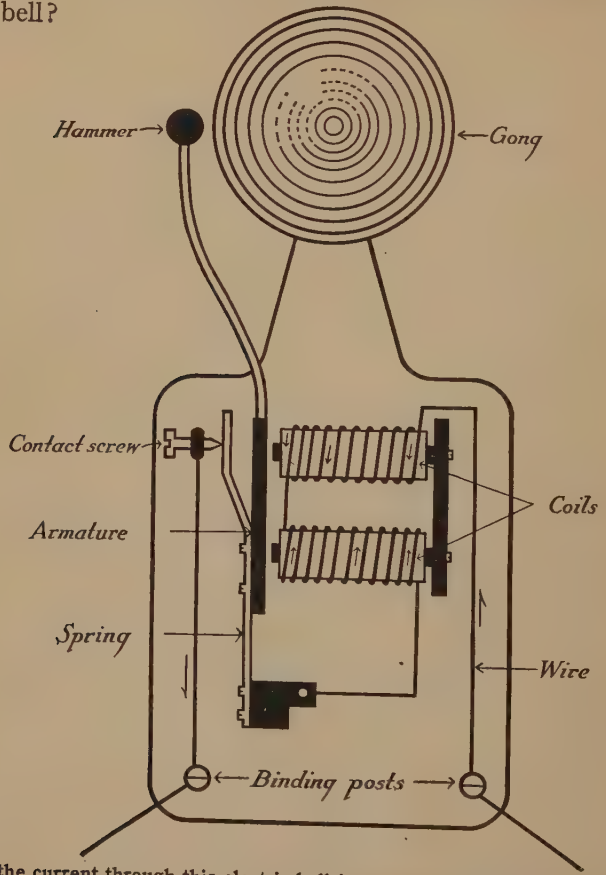
Problem 2 — How an electric bell rings

Class Problem. — Make a demonstration board, three feet long and two and one-half feet wide. Use boards of soft wood, cut the proper lengths, and fastened together with cleats on the back. With small screws fasten an electric bell and a push button to the demonstration board. Set a dry cell on the table just in front of the board. Connect the cell, push button, and electric bell with pieces of copper wire.

Push the button. Watch the bell ring. How does the hammer move? In how many directions does it move? What is the hammer attached to? How does the armature move? In how many directions does it move?

What makes the hammer hit the bell? Trace the current of electricity from one binding post to the other. Notice that the armature touches the contact screw. How does

the electric current affect the coils of the magnet? What happens to the armature? Why does the hammer hit the bell?



Trace the current through this electric bell from one binding post to the other

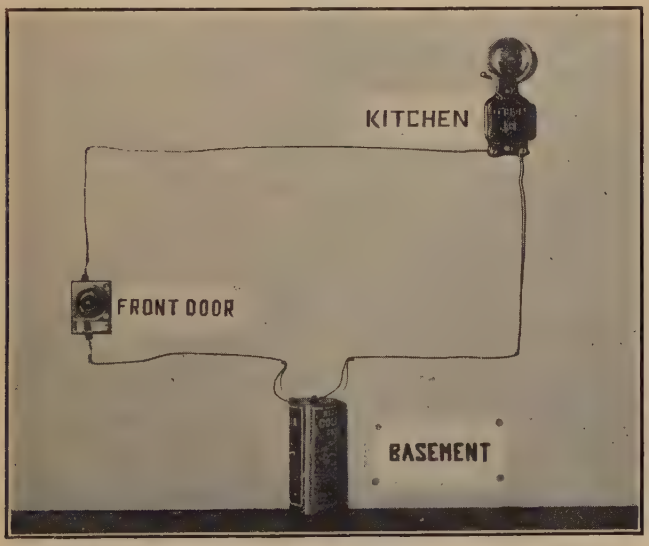
What makes the hammer fly back? With the fingers push the armature against the electro-magnet. Does the armature touch the contact screw now? Can electricity pass through the coils? Why do the coils lose their magnetism?

What is the purpose of the spring? Explain how the bell continues to ring.

Turn the contact screw in. Why does the bell ring faster? Turn the contact screw out again. Why does the bell ring slower? Why does the bell stop ringing if you turn the screw out too far? If you turn the screw in too far?

Problem 3 — How to connect electric bells

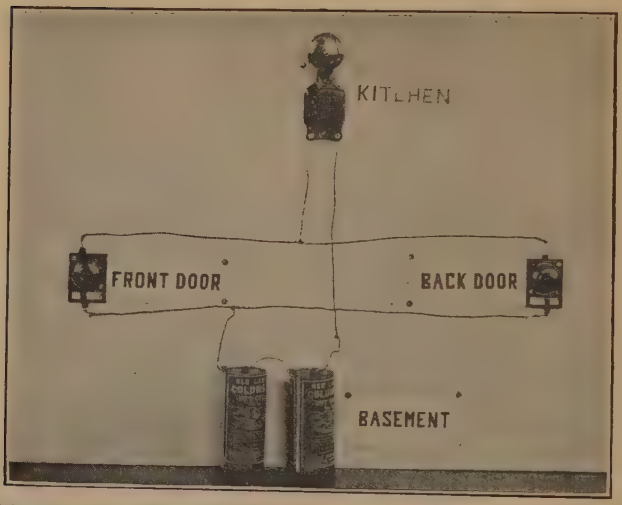
Home Problem. —Study your electric bell system at home. Locate the bells, push buttons, and cells. If you



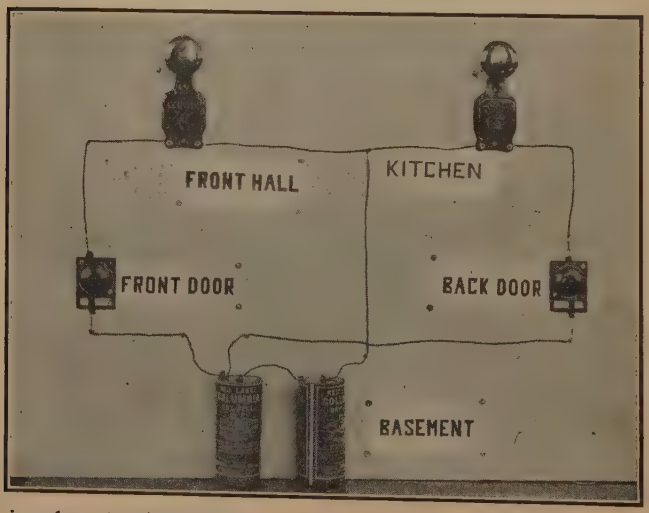
Single bell system. Make a board like this for wiring practice

use a bell ringing transformer, notice how this is connected. Draw a plan of your bell system and show the different circuits. Label all parts neatly.

Class Problem. — (*a*) *A simple bell system. One electric bell, one push button, and one dry cell.* Attach the bell and push button to the demonstration board. Set a dry



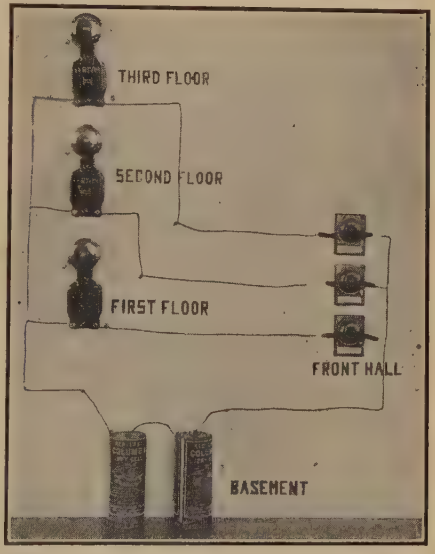
Wiring plan: one bell and two push buttons. Either button rings the bell



Wiring plan: two bells and two push buttons. Each button rings one bell

cell in front. Connect the bell, push button, and cell with pieces of copper wire. Screw the cover off the push button. How is it made? Push down the brass spring. Why does the bell ring? Release the brass spring. Why does the bell stop ringing?

(*b*) In some bell systems, there is an electric bell in the hall or kitchen, a push button at the front door, and a second push button at the back door. Either push button will ring the bell. Attach an electric bell and two push buttons to the demonstration board. Use two dry cells. Connect as shown below. Push the front door button. What happens? Push the back door button. What happens? Trace the complete circuit for each push button.



Wiring plan for an apartment house. Trace the current for each floor

(*c*) Some houses have two bells in the hall or kitchen, a push button at the back door, and a second push button at the front door. Connect this system as shown above.

(*d*) Bell systems for apartment houses are usually arranged as follows: In the main entrance hall, there are one or more rows of push buttons, with name plates under them. Each button rings a separate bell in each apartment. Connect this system as shown above, using three bells and three push buttons. Test each circuit by pushing the button.

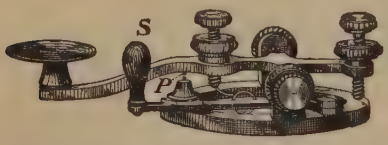
PROJECT IV

HOW MESSAGES ARE SENT BY TELEGRAPH

Problems — 1. The parts of a telegraph set.
2. How the key and sounder work.

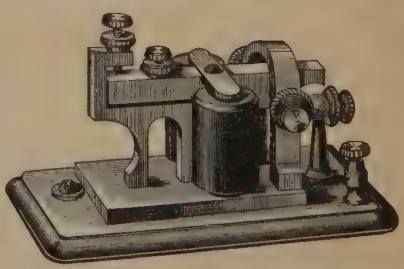
Problem 1 — The parts of a telegraph set

Class Problem. — Examine a telegraph key. Where do you attach the wires? Press down the brass lever. How does electricity pass from one screw binding post to the other? What is the purpose of the contact points? Release the lever. Why does it snap back? Point out the spring. Close the switch and show how electricity passes through the key. What is the purpose of the adjusting screw?



Telegraph key. It completes the circuit

Examine a telegraph sounder. Point out the screw binding posts, pivots, coils, spring, armature, and adjusting screws. How does the electric current flow from one screw binding post to the other? What effect does this have on the coils? Explain how the coils are made. Locate the brass rod and steel cross bar of the armature. Why is this bar made of steel? Press down the brass rod. Release it. Why does it snap back? Make a drawing of a telegraph key and sounder. Label all parts neatly.

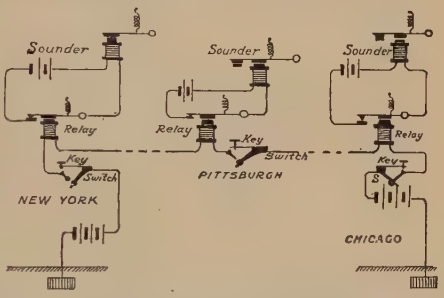

Telegraph sounder. It makes the click

Problem 2 — How the key and sounder work

Class Problem. — Connect a telegraph key, sounder, and two dry cells.

Press down the key. Watch the armature of the sounder. Trace the complete circuit through the key, sounder, and dry cells. How does this electric current affect the coils of the sounder? What pulls the armature down? Explain how the first click is made.

Release the key. Why does it snap back? Notice the contact points now. Do these points touch? How does this affect the circuit? The armature? What makes the armature snap back? Explain how the second click is made.



A telegraph system. On long lines "relays" are used as the current on the main wire is not strong enough to move the sounder

Press down the key and release it instantly. Note the time interval between the two clicks. This represents a dot. Hold the key down for about a second, and then release it. Note the time interval. This represents a dash. Study the Morse Code given below.

INTERNATIONAL MORSE ALPHABET

A	·—	J	·— — —	S	···
B	—···	K	—·—	T	—
C	—·—·	L	·—··	U	··—
D	—··	M	— —	V	···—
E	·	N	—·	W	·— —
F	··—·	O	— — —	X	—··—
G	— —·	P	·— —·	Y	—·— —
H	····	Q	— —·—	Z	— —··
I	··	R	·—·		

PROJECT V

THE ELECTRIC MOTOR AND HOW IT RUNS

Much of the hard work in our homes is now done by the electric motor. It is used to sweep rugs, dust furniture, wash clothes, grind knives, chop meat, run sewing machines, and pump water. Have you a toy electric motor at home? Take this motor to school and show the class how it runs.

Problems — 1. The parts of an electric motor.
2. How electricity produces motion.
3. How the poles of the armature change.
4. How an electric motor runs.

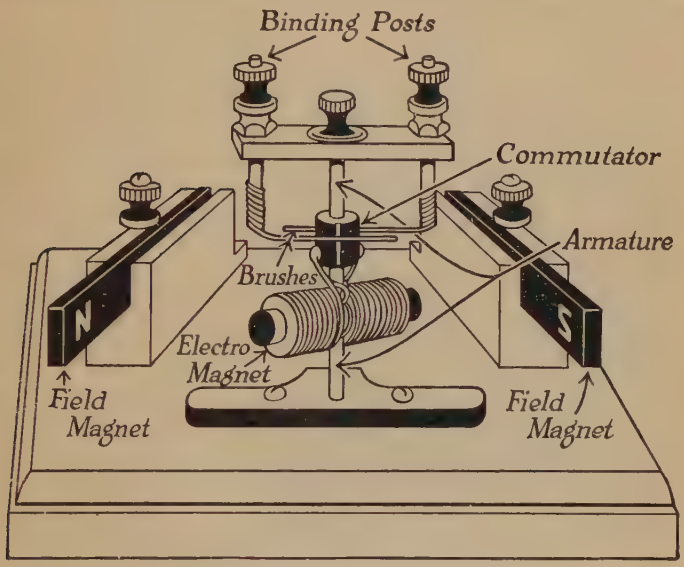
Problem 1 — The parts of an electric motor

Use a St. Louis motor to work out the following problems. It can be taken apart easily. It is also simple in construction, and shows clearly the principles of an electric motor.

Class Problem. — Examine the parts of a St. Louis motor. Notice the two bar magnets. These are called field magnets. Locate the vertical shaft with the coil of wire. Make it revolve by tapping with the finger. This is called the armature. The soft iron core wound with insulated wire is an electro-magnet. Just above this, you will find a hard rubber ring, with two metal strips on the outside. This is called a commutator. Do the edges of the metal strips touch? Hard rubber is an insulator. What does this mean? Can electricity pass directly across from one metal strip to the other? Where are the ends of the copper wire of the electro-magnet attached? Notice the two horizontal steel wires. These are called brushes. One end of each brush rubs against the brass strips of the com-

mutator. The other end of each brush is connected with a binding post at the top of the motor.

Place the field magnets in position, taking care that the north pole of one magnet is opposite the south pole of the



A St. Louis motor — the simplest kind to study

other. Connect two dry cells from carbon to zinc. Attach wires from these cells to the binding posts at the top of the motor.

Watch the motor run. How does the armature move? How does electricity flow from the binding posts to the commutator? Where does this electricity go from here? Trace the current from one side of the commutator, around the electro-magnet, and back to the other side of the commutator. What effect does the electricity have on the revolving coil? Don't run the motor longer than a few seconds at a time. You will "run down" the dry cells.

Problem 2 — How electricity produces motion

Class Problem. — With silk cord suspend a bar magnet from a wooden support, so that it hangs horizontally. Hold another bar magnet in one hand. Bring the north pole of this magnet near the north pole of the suspended magnet. Don't let them touch. What makes the suspended magnet revolve? Bring the south pole of the magnet held in the hand near the south pole of the suspended magnet. *What happens?* Bring the two north poles close together again, and hold the magnet in the hand still. How far does the suspended magnet turn? What happens when two unlike poles come together?

Like poles push each other away

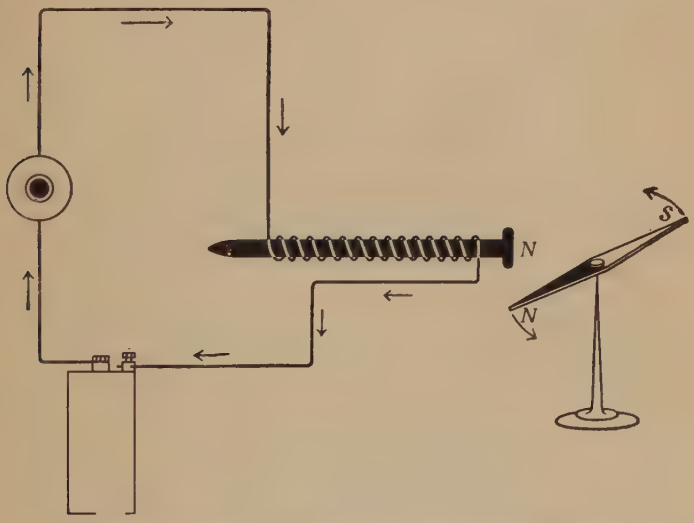
Again bring the north pole of the hand magnet near the north pole of the suspended magnet. When the suspended magnet makes a half turn, reverse the hand magnet, bringing the south pole near the south pole of the suspended magnet. Continue to reverse the poles of the hand magnet for every half turn of the suspended magnet, always bringing like poles close together. Why does the suspended magnet keep revolving?

The suspended magnet represents the armature of an electric motor. The hand magnet represents the field magnets. In a real motor the poles of the armature are reversed. The poles of the field magnets do not change.

Real motors also use electro-magnets in the place of steel bar magnets.

Problem 3 — How the poles of the armature change

The operation of an electric motor depends upon the changing of the poles of the armature. The following problem will show you how the north pole of an electro-



When the direction of the current changes the poles change

magnet is changed to a south pole, and the south pole to a north pole.

Class Problem. — (*a*) Wind a large wire nail, about five inches long, closely and evenly with insulated copper wire. Connect this electro-magnet with a dry cell and a push button. Bring the blunt end of this magnet near the north pole of a compass needle. Don't bring it too close. Press the button. What happens? Is the blunt end a north or a south pole? Bring the pointed end of the nail

near the north pole of the needle, and press the button. Which pole is the pointed end?

Electricity flows out of a dry cell from the carbon terminal. Trace the current from the carbon of one cell, around the nail, and back again to the zinc of the second cell. What is the direction of the current around the nail? Does it flow from the pointed end toward the blunt end, or just the reverse?

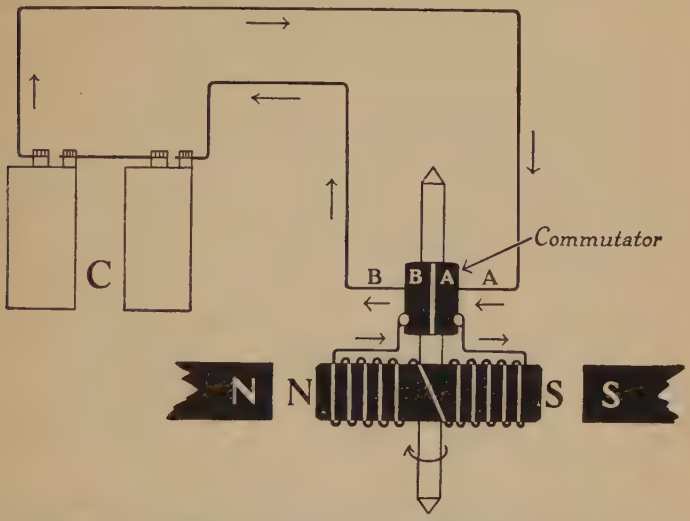
Interchange the wires at the terminals of the dry cells. Attach the "zinc" wire to the carbon terminal, and the "carbon" wire to the zinc terminal. Now trace the current from the carbon of one cell, around the nail, and back again to the zinc of the second cell. What is the direction of the current around the nail now? Compare this direction with the direction of the current before the wires were interchanged.

Now bring the blunt end of the nail near the north pole of the compass needle, and press the button. What happens? Is the blunt end a north or a south pole now? Test the pointed end of the nail in the same way. Which pole is the pointed end? Explain how the poles of this electromagnet have been changed.

(*b*) *Take a St. Louis motor apart.* Set the armature back in the frame. Hold the ends of the copper wires *A* and *B* from the dry cells *C* against the metal strips *A* and *B* of the commutator. With a compass needle locate the north and south poles of the coil. Now trace the direction of the current from the carbon of the dry cells to one side of the commutator, around the coil, to the other side of the commutator, and back again to the zinc of the cells.

Now give the armature a half turn, so that brush *A* touches metal strip *B*, while brush *B* touches metal strip

A. Again locate the north and south poles of the coil with the compass needle. Trace the direction of the cur-



Trace the current from one side of the commutator to the other. What happens when the armature revolves?

rent. Does it flow in the same direction? Why have the poles of the coil changed? What happens when the armature makes another half turn? What is the purpose of the commutator?

Problem 4 — How an electric motor runs

Class Problem. — Place the bar magnets of the St. Louis motor in position with north and south poles opposite. Set the armature in the frame, so that it will revolve. Connect two dry cells. Hold the ends of the two copper wires from these cells, one wire against each metal strip of the commutator. Give the armature a gentle push. What happens? Why does the armature keep revolving? What happens when like poles of the field magnets and armature

are near each other? Why is the current reversed when the armature makes a half turn? How does this affect the poles of the armature? The turning of the armature?

Put back the other parts of the motor and run it again. Explain the use of the brushes. Why do strong field magnets make a motor run faster? What kind of field magnets are used in commercial motors? The armatures of some motors have many poles. Why are these motors more powerful than a St. Louis motor?

PROJECT VI

HOW WE PLATE THINGS WITH ELECTRICITY

Problems — 1. Why some articles are plated.
2. How to do copper plating.

Problem 1 — Why some articles are plated

Home Problem. — Examine some of the following articles at home.

Kitchen utensils	Lighting fixtures	Door plates
Bathroom fixtures	Jewelry	Hinges
Ornaments	Cutlery	Stoves
Clocks	Bells	Toys

Do you find any articles plated with gold? Silver? Nickel? Copper? Brass? Tin? Zinc?

Make a list of all the plated articles you find at home. Arrange them neatly in a table.

Why are watches plated with gold? Spoons with silver? Door plates with brass? Cans with tin?

Problem 2 — How to do copper plating

Class Problem. — Examine a few crystals of copper sulphate. Describe this substance. What is it composed of? Put about half a pound of copper sulphate into one quart of water and let it stand overnight. Notice that only part of the copper sulphate dissolves.

Fill a quart battery jar three-quarters full of the copper sulphate solution.

Connect two dry cells in parallel, carbon to carbon and zinc to zinc, as shown in the illustration. Now take a

carbon rod from an old dry cell, and a small strip of copper. With short pieces of wire, connect the carbon rod to a zinc binding post, and the copper strip to a carbon binding post.

Lower the carbon rod and strip of copper into the solution of copper sulphate. Don't let them touch. Trace the electric current from the carbon of the cells, to the copper strip, through the solution, to the carbon rod, and back again to the zinc of the cells. Let the carbon rod stay in

Notice the carbon rod. Copper plating is easy to do

the solution for several minutes, then take it out and examine it. What do you find? Where does this copper come from? The electric current flowing through the solution separates copper from the copper sulphate. The liquid then dissolves more of the copper from the copper strip. Where does the copper go? The copper strip is slowly used up. What becomes of it? Explain how the copper sulphate is used up and formed at the same time.

Reverse the copper wires, attaching the wire from the carbon rod to the carbon of the cells, and the wire from

the copper strip to the zinc of the cells. Put the carbon rod and copper strip back into the solution, and let them stay there for several minutes. Examine the carbon rod again. What happened to the copper? Where is this copper now? Explain how plating depends on the direction of the current.

Copper plate the blade of a knife. A wire nail. A teaspoon. Each article should be cleaned thoroughly with fine sandpaper before plating.

PROJECT VII

HOW ELECTRICITY IS STORED

Storage batteries are very common to-day. Hundreds of thousands are used in automobiles for lighting, starting, and ignition. Big cities use more electricity during the night than during the day. To meet this extra demand it is necessary for electric plants to store the excess electricity made during the day in storage batteries. In this way there is an extra supply to draw from during the rush hours at night.

Problem 1 — How to make a storage battery

Class Problem. — Take two pieces of sheet lead, four inches wide and six inches long. Punch a small hole in each piece near the top. Slip one end of a copper wire through each hole and twist it tightly.

Pour three drinking glasses of tap water into an agateware pan. Now add very slowly a glass of concentrated sulphuric acid.

(*Caution.* — Don't spill the acid on your hands or clothes. Always pour sulphuric acid into the water. Never pour water into the acid.)

Let the mixture of sulphuric acid and water cool.

Pour this mixture into a quart battery jar until it is three-quarters full. Lower the lead plates into the jar. Make sure the wire connections are tight. The storage battery is now complete.

How to charge the battery. Connect four new dry cells from the carbon of one to the zinc of the next. Attach the wires from the lead plates to the cell terminals. Electricity is now passing into the battery. It is being charged.

Notice the bubbles on each plate. Hydrogen bubbles collect on one plate and oxygen bubbles on the other.

Let the battery charge for a few minutes. Now disconnect the dry cells, and attach the wires from the lead plates to

A home-made storage battery. It rings the bell

the binding posts of an electric bell. *What makes the bell ring?* Where does this electricity come from?

Take the plates out of the jar and examine them. Notice that the surface of one plate is covered with a brownish substance. This is called lead dioxide. It is a compound of lead and oxygen. Where did the lead come from? The oxygen? What happens to these elements when a storage battery is being charged? What kind of action is this? Is electricity really stored in the battery?

PROJECT VIII

HOW HEAT IS PRODUCED BY ELECTRICITY

Electricity heats any wire that it passes through, more or less. The amount of heating depends upon the amount of electricity passing through, the size of the wire, and the materials of which the wire is made. A large current heats a wire more than a small current. Fine wires become hot quicker than thick wires. Wires made of iron or German silver are heated more than those made of copper or silver. We frequently say that fine wires have a higher resistance than thick wires, and wires made of such materials as iron or German silver have higher resistances than those made of such materials as copper or silver. The wires of all electric heating appliances, such as stoves, flat irons, and toasters, are composed of materials which have high resistances.

Problems — 1. How an electric current heats a wire.
2. How an electric bread toaster works.

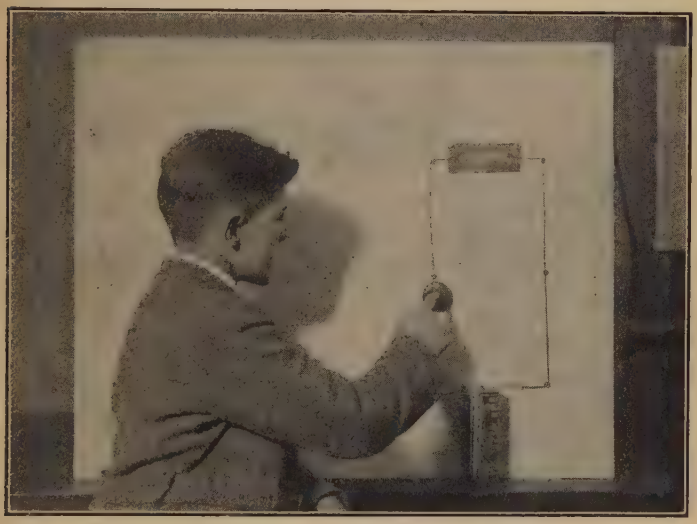
Problem 1 — How an electric current heats a wire

Class Problem. — Set up the demonstration board, described under Problem 2, page 273. Place two dry cells on the table, just in front of the board. Connect these cells from the carbon of one to the zinc of the next. Fasten a push button to the mounting board. Connect the push button and dry cells as shown in the illustration. Use tacks to hold the wires in place. The ends of the two wires should be about two inches apart.

Unravel a single strand of iron picture cord wire and break it off, so that it is about four inches long. Twist

the ends of this strand around the ends of the two copper wires.

Press the button for one or two seconds. What happens? Why does the iron wire become red hot? Remove the iron wire and replace it with a piece of fine copper wire. Press the button again. Does the copper wire become



Press the button. Watch the iron wire turn red

red hot? Which is heated more, the iron wire or the copper wire? Which wire offers the higher resistance? Which wire would be more suitable to use in an electric iron?

Problem 2 — How an electric bread toaster works

Class Problem. — Use an electric bread toaster in which the wires are clearly visible. *Examine this toaster.* How is the wire arranged? Trace the wire from one terminal to the other.

Screw the plug into a lamp socket and turn on the electric current. Notice the wire. What heats it red hot? Put a slice of bread in the toaster. What toasts the bread? Hold one hand near the toaster. What do you notice? Touch the wire with the head of a match. These wires are usually made of an alloy of metals called *nichrome.* Why is nichrome used? Explain how the nichrome wire is heated by the electric current.

FACTS EVERY ONE SHOULD KNOW ABOUT ELECTRICITY

Early Discoveries. — Stroke a cat's back when its fur is cold, and hear it crackle. Watch your mother's hair follow the comb. Rub a fountain pen on your sleeve, and pick up bits of paper. The Greeks, without realizing it, made electricity in a similar manner over twenty-five hundred years ago. They noticed that amber, when rubbed with certain fabrics, attracted paper and other materials. In fact, our word electricity comes from *elektron*, which was the Greek name for amber.

About 120 years ago, Galvani, an Italian physician, hung the legs of a frog from an iron rail, with a piece of copper wire. As the frog's legs accidentally swung back and forth, he noticed that they twitched when they struck the iron rail. This chance observation was of great importance, for it led Galvani to the discovery of the electric cell.

Sal-ammoniac Cell. — One of the simplest cells to study consists of two metal strips, one of copper and the other of zinc, immersed in a solution of water and sulphuric acid. This cell will ring an electric bell or light a small bulb. It makes electricity by chemical action. The tiny bubbles that you see are filled with hydrogen. The hydrogen carries small charges of electricity through the liquid to the copper strip, where it is given up. Electricity made in this cell is "collected" by the copper strip and flows through it, out of the cell. The sal-ammoniac cell usually consists of a carbon cylinder, zinc rod, and a strong solution of sal-ammoniac and water. It is used mostly for ringing door bells. Sal-ammoniac is a white salt, which contains ammonia, hydrogen, and chlorine. When the cell is working, zinc is used up. It unites with chlorine to form another

substance, called zinc chloride. Bubbles of hydrogen, and ammonia are set free and escape from the liquid. Sal-ammoniac cells last for many years. All you need to do, when they become weak, is to put in a new zinc rod and a fresh solution of sal-ammoniac.

Dry Cell. — Dry cells are in common use. Millions are sold yearly. These consist of a zinc can, containing a mixture of sal-ammoniac, water, and manganese dioxide, with a carbon rod in the center. Electricity is generated by chemical action. Look at the outside of a worn-out dry cell. The zinc is eaten full of holes, and covered in spots with a white salt. This white salt is zinc chloride. A current of electricity flows out of a dry cell through the carbon rod.

A stream of water flowing from an open faucet may be large or small. It may run slowly, or with great force. In a similar way a stream of electricity flowing through a wire may be large or small. It may run slowly, or with great force. We measure the amount of water that flows from the faucet in gallons. The force, or pressure, of this stream of water may be measured in pounds. We measure the current of electricity that flows through a wire in *amperes*. The force, or pressure, of the stream of electricity may be measured in *volts*. When you buy dry cells, have them tested with an *ammeter* and a *voltmeter*. The current of electricity from a new dry cell should measure at least twenty-five amperes, with a force of 1.5 volts.

Magnets. — Magnets may be divided into two general classes, natural magnets and those made by man. Certain pieces of common iron ore, when dug out of the ground, are natural magnets. They attract iron or steel. This ore is called lodestone, or leading stone, because it always

points north and south, when hung from a thread. Man makes two kinds of magnets, steel magnets and electro-magnets. Steel magnets are made by passing an electric current around a bar of steel. This bar may be straight or shaped like a horseshoe. One end of the bar is marked *N*, the other end *S*. *N* stands for north pole, *S* for south pole. When two north poles, or two south poles, are brought close together, they push each other away. Hence we say, "*Like poles of magnets repel.*" When a south pole is brought near a north pole, they cling together. Hence we say, "*Unlike poles of magnets attract.*" The poles of magnets are surrounded by invisible lines of force. These can be shown by sprinkling iron filings on a sheet of paper, placed over two magnets. When a north pole is placed near a south pole, the iron filings arrange themselves in curved lines, reaching from one magnet to the other. They seem to act like tiny elastic bands, trying to pull the magnets together. When like poles are placed near each other, the curved lines meet in the center and are bent back. The invisible lines of force from one pole seem to push against those from the other pole.

Suspend a magnet from a thread, so that it hangs horizontal, and you have a compass. Compasses are used by hunters, explorers, and sea captains to guide them. The north pole of a compass does not point toward the geographic north pole, the pole that Peary discovered. It points toward the magnetic north pole, a place located west of Hudson Bay.

Electro-magnets. — In 1819, Oersted of Copenhagen made a great discovery. He noticed that a compass needle moved when brought near a wire through which a current of electricity was flowing. This observation led to the discovery of electro-magnets, which are used in bells, tele-

graph instruments, telephones, motors, and dynamos. Wind a length of insulated copper wire around a piece of soft iron, like a nail, and send a current of electricity through the wire, and you have an electro-magnet. As long as an electric current flows through the wire, the nail will pick up bits of iron or steel. When the current stops, the nail loses its magnetism. The strength of an electro-magnet depends on the number of turns of wire around the soft iron core, and also on the amount of electricity flowing through the wire. Powerful electro-magnets that lift many tons are made by winding thousands of turns of insulated wire around the core and sending a large current of electricity through it.

You have seen how an electric door bell rings. Two cores of soft iron are wound with coils of wire. This is an electro-magnet. A flat piece of iron, called an armature, is placed near one end of the coils. A metal hammer is attached to the flat piece of iron, so that it strikes a gong when the armature vibrates. The armature is held against a small contact screw by a spring. When you press the button, electricity flows through the coils, making them magnets. The armature is pulled away from the contact screw, against the ends of the coils, and the hammer hits the gong. A small space is now left between the contact screw and the armature, thus breaking the circuit. Electricity stops flowing through the coils. They lose their magnetism. The armature is released, and springs back against the contact screw; and the hammer moves away from the gong. This completes the circuit a second time. The coils become magnets, attract the armature, and the hammer hits the gong again. These changes take place very quickly, so that the armature vibrates rapidly, and makes the bell ring.

A telegraph sounder works something like an electric bell. An electro-magnet consisting of two coils of wire is attached to a board. Just above these coils is placed a steel bar fastened to a bar of brass. This is called an armature. The brass bar rocks up and down on a pivot. The end of this bar is placed between two screws. When it goes up, it strikes one screw and makes a click. When it goes down, it strikes the other screw and makes a second click. The time intervals between the two clicks may be long or short. A long interval is called a dash, a short interval a dot. The letters of the alphabet are represented by dots and dashes.

You can also send messages with an electric spark through the air. All you need is a spark coil, key, dry cells, and a few pieces of copper wire. Electrical waves of different lengths travel through space, and may be detected with a crystal of galena and a pair of telephone receivers. When you put these receivers over your ears, you can hear the long or short " buzz " of the spark, and read the message many miles away, if you know the dots and dashes of the wireless code.

Screw off the cover of a telephone receiver and examine it. You will find a piece of thin metal, called a diaphragm, placed over the coils of a magnet. There is a similar metal diaphragm in the transmitter, the part of the telephone that you speak into. When you talk into a telephone, the diaphragm of the transmitter vibrates back and forth. These vibrations send currents of electricity in rapid succession through wires to a telephone receiver, perhaps hundreds of miles away. The coils of the electro-magnet in the receiver become stronger, or weaker, as the rapid succession of electric currents are sent from the transmitter. This causes the thin metal diaphragm of the receiver to vibrate

in unison with the transmitter diaphragm, and your voice is reproduced. One of the greatest inventions of modern times is the wireless telephone. Music, or the human voice, can be sent for thousands of miles without any wires. Perhaps you have listened to a wireless concert. If you have, you must have marveled at the work of some of our inventors of to-day, who made this wonderful performance possible.

Electric Motors. — The electric motor is a great blessing to mankind. It uses the power of distant waterfalls either to run factories and subway trains, or to take the drudgery out of housework by cleaning rugs and washing clothes. Simply press a button and it does its work quickly and efficiently, without noise or smoke, whether it is the tiny motor of a vacuum cleaner, or the big motor of a powerful locomotive.

The easiest way to study a motor is to take two bar magnets. Suspend one magnet by a thread so that it hangs horizontal. Let this represent the armature. Take the other magnet in one hand. Let this represent the field magnets of a motor. Bring a north pole of the field magnet near the north pole of the armature. The like poles repel each other, and the armature makes a half turn and then stops. Now reverse the field magnet, bringing a south pole near the south pole of the armature. Again the like poles repel each other and the armature makes another half turn. Now reverse the field magnet, for every half turn of the armature, always bringing like poles together. The armature continues to revolve rapidly.

The armature and usually the field magnets of real motors are electro-magnets. The poles of the field magnets do not change. Instead of this, the armature poles keep changing, always bringing like poles of the field magnets

and armature close together. Thus the poles of the armature are continually repelled, and it is pushed around very rapidly.

The poles of an electro-magnet change when the direction of the electric current changes. You proved this with the wire nail wound with insulated wire. At first the head of the nail was a north pole, and the pointed end a south pole. When you reversed the wires at the terminals of the dry cells, you reversed the direction of the electric current. The head of the nail changed to a south pole, while the pointed end of the nail became a north pole. In a " direct current " motor, such as we have described, the direction of the current is constantly changed by the revolving commutator. The commutator is made of segments of brass or copper, separated by some insulating material such as rubber. When it revolves, electricity flows from the brush first into one segment and then into another. The ends of the wires wound around the coils of the armature magnets are connected with different segments of the commutator. Hence electricity flows through these coils, first in one direction, then in the other, and the poles keep changing.

Only a very small quantity of electricity is generated by friction or chemical action — far too small to run trolley cars or light the electric bulbs in your home. Have you ever seen a dynamo or generator? It looks like an electric motor. In fact, if you put a belt around the iron shaft of the armature of a St. Louis motor and make the armature revolve very rapidly, you have a generator. Electricity flows out through the commutator, along the brushes, and out of the binding posts at the top. Disconnect the dry cells, and attach the wires to a small bell, and it rings. Michael Faraday, an English scientist, discovered the principle of the dynamo about the middle of the nine-

teenth century. He noticed that when a steel magnet is moved back and forth through a coil of wire, a current of electricity is generated.

Place two bar magnets with a north pole opposite a south pole and rotate a coil of wire between them. A current of electricity will flow through the coil, and you have a simple generator. As you know, there are many invisible lines of force stretching between the poles of these two bar magnets. When you rotate the coil, the wires cut these invisible lines of force. The greater the number of lines of force extending across from one pole to the other, and the faster you cut them, the greater is the quantity of electricity generated. For these reasons, dynamos of big power plants have powerful field magnets, with millions of invisible lines of force between the poles. The armature, which is turned very rapidly by steam or water power, is made of thousands of windings of insulated copper wire. In this way, many lines of force are cut every second by the revolving armature, and a large quantity of electricity is generated.

Electro-plating. — Electro-plating is an interesting process. Many articles are plated with copper or nickel to keep them from rusting. Spoons are plated with silver and watches with gold to make them look better. The pages of this book are printed from electrotypes. First an impression of the type is made in wax. This is covered with powdered graphite and hung in a copper sulphate solution. When an electric current is passed through the solution, a copper plate is formed over the wax impression. The wax is next melted out and molten metal poured over the back of the copper plate to stiffen it.

When you lower a copper strip and carbon rod into a solution of copper sulphate and pass an electric current

through it, a plate of metallic copper is deposited on the carbon rod. Electricity takes copper out of the solution. This copper travels through the solution to the carbon rod. At the same time, the copper strip is slowly dissolved, and more copper passes into the solution.

Gold, silver, and nickel plating are done in the same way as copper plating. Instead of a copper strip, a piece of gold, silver, or nickel is used; and in the place of the copper solution, a solution of gold, silver, or nickel.

Storage Batteries. — Storage batteries are so common that you have doubtless seen them. They are used in almost every automobile for starting, lighting, and ignition. When you examine the outside of a storage battery, you see only a black box with lead strips at the top. If you try to lift this box, you will find that it is very heavy. Inside, there are a number of lead plates immersed in a strong solution of sulphuric acid and water. To charge a storage battery, wires are connected with the lead terminals and a current of electricity is passed through it, sometimes for several hours.

A simple storage battery can be made by attaching copper wires to two lead strips and lowering them into a jar containing a strong solution of sulphuric acid and water. To charge this battery, pass an electric current through the solution. You will notice many bubbles of gas. Some of these bubbles contain oxygen, others contain hydrogen. You will also notice that a brownish substance forms on one of the lead plates. This substance is lead dioxide. It is formed by the uniting of lead and oxygen. Electricity is not really stored in the battery. Chemical action takes place and lead dioxide is formed. When you use this battery to ring a bell, or light a small electric lamp, chemical action again takes place. Lead dioxide is slowly used up,

so that the brownish substance disappears. Hence, electricity is generated in much the same way that it is in an ordinary dry cell.

When electricity passes through any wire, the wire is heated. The amount of heating depends on the strength of the current, the thickness of the wire, and the material of which it is made. A large current heats a wire more than a small current. A thin wire becomes hotter than a thick wire. Wires made of such materials as iron or German silver are heated more than those made of silver or copper. This heating is due to the resistance the wire offers to an electric current. A thin wire offers a greater resistance than a thick wire. An iron wire offers a greater resistance than a copper wire. For this reason, electric heating appliances are made with wires which offer a very high resistance. Electric stoves, flat irons, chafing dishes, radiators, and bread toasters are made with nichrome wires. When an electric current passes through these wires, they become red hot, because nichrome has a very high resistance. The filament of a Mazda lamp is made of fine tungsten wires. The filament is heated white hot for two reasons. In the first place, tungsten is a metal which has a high resistance. In the second place, the wire is so thin that its resistance is increased still more. Scientists will probably discover new substances which offer resistances even higher than nichrome or tungsten. When they do, we may have more efficient electric heaters and brighter lamps, for both heating and lighting with electricity depend on *resistance.*

CHAPTER IX

THE CLOTHES WE WEAR

It is true that clothes do not make the man. They help, however, much more than you or I realize, for people are apt to judge us by what we wear. They seem to respect us more and have more confidence in our ability, when we wear neat, sensible clothes.

We all like to dress well. This does not mean showy clothes, extreme styles, or gaudy colors. It means rather, the ability to select comfortable, seasonable clothing that looks well and wears well.

In order to be well dressed, you will need to exercise good taste and good judgment when you buy clothes. You will need to know something about the different kinds of fabrics and how they are woven. You will need to know how to test cloth fibers and be able to detect frauds. You will also need to know something about the cleansing of fabrics, the removal of stains, and how to dye clothing materials. You will be given an opportunity to study some of these important problems in the following chapter.

PROJECT I

THE KINDS OF CLOTH WE WEAR

Problems — 1. What clothes are made of.
2. A study of cloth samples.

Problem 1 — What clothes are made of

Class Problem. — Most of the cloth you buy is made of one or more of the following kinds of fibers:

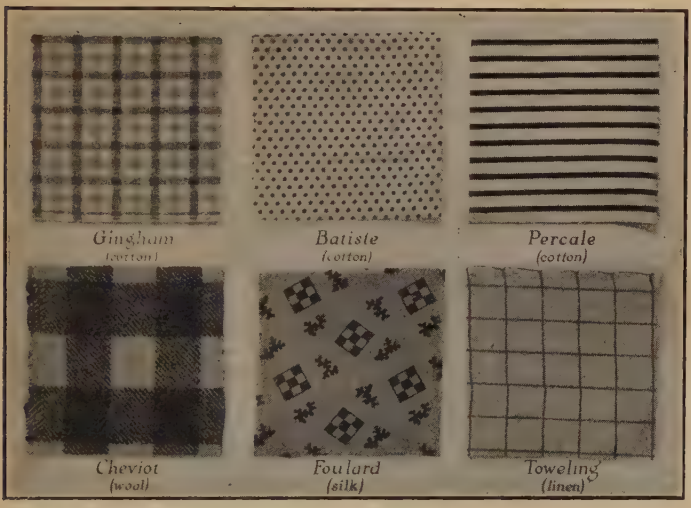
Animal Fibers	Vegetable Fibers
Wool	Cotton
Silk	Linen
	Artificial silk

Let each member of the class examine fibers of wool, silk, cotton, linen, and artificial silk. Describe the appearance of each. Where does each kind of fiber come from? How is it made into cloth? Test the strength of each fiber by trying to break it. Why is woolen underwear warmer than cotton? Why does linen wear longer than cotton? Explain why linen makes better towels or napkins than cotton. What are some of the merits of silk for clothing?

A cotton boll. The pod has burst open, showing the fibers

Problem 2 — A study of cloth samples

Home Problem. — Cut out cloth samples, about an inch square, from remnants of discarded clothing at home. Glue



You can make an attractive collection of cloth samples. Arrange them like this

these samples in your notebook, or on a sheet of paper, arranging them neatly. Determine the kind of cloth in each sample. Print the name under each square.

PROJECT II

HOW CLOTH IS WOVEN

Problems — 1. How fibers are made into yarn.
2. How cloth is put together.
3. How to weave a piece of cloth.

Problem 1 — How fibers are made into yarn

To-day fibers are spun into yarn, for weaving cloth, by machinery. Huge spinning frames twist the fibers and draw them out into long, strong threads. Our grandmothers spun wool on a large, wooden wheel. Even primitive peoples knew how to weave. They were compelled to spin all their fibers by hand.

How fine a thread can you spin by hand?

Home Problem. — Pull out a handful of cotton fibers from a roll of cotton batting. Arrange some of these fibers in the form of a rope three or four inches long and about as thick as a match. Twist this cotton rope between the fingers, for several minutes, and draw it out little by little until you have spun a strong cotton thread. Make several trials, if necessary. Try to make one fine enough to go through the eye of a needle. Take some of these threads to school, for inspection.

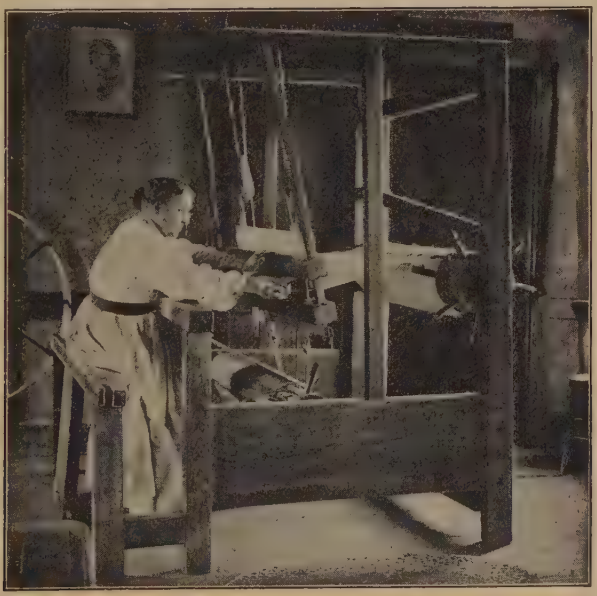
Problem 2 — How cloth is put together

Home Problem. — Cut out inch squares of several kinds of cloth. Examine these pieces of cloth closely. Notice that the threads run both ways. The threads running lengthwise are called the *warp*. The crosswise threads are called the *woof*.

Unravel a piece of cloth. Pull out the threads of the woof, one by one. How are these threads arranged? How are they held in place? Notice how the threads of the warp are crossed. What is the purpose of this? Examine other pieces of cloth in the same way.

Problem 3 — How to weave a piece of cloth

Cloth is woven on a loom. The crude looms of the Indians, the clumsy looms of colonial days, and modern



In colonial days cloth was woven on hand looms, at home

power looms — all work on the same general plan. The warp threads are held in a frame, and are separated into two or more layers by raising and lowering alternate threads. The woof thread is wound on a bobbin, and unwinds when the bobbin is thrown back and forth between the layers of the warp. There is also a device to cross alternate warp

Weaving a piece of cloth. Put the needle under one thread and over the next

threads, by moving them up and down, each time the woof thread is thrown across.

Home Problem. — Weave a small piece of cloth at home. Use woolen yarn, if you have any; otherwise, use crochet cotton or linen thread. Take a small pasteboard box, three or four inches wide, such as a candy box. Thread a large darning needle with a piece of woolen yarn about six feet long. Push the needle through the sides of the box, near the top edge, and pull the yarn through. Sew

back and forth across the top of the box about sixteen times, closely and evenly. This layer of yarn is called the warp. Knot the ends of the yarn to keep them from pulling through.

Thread the needle again with a piece of woolen yarn about eight feet long. Now sew across the warp. Pass the needle under one strand of the warp and over the next, and pull the yarn through. This is the first strand of the woof. Bring the needle around the last strand of the warp, and sew back again, in the same way. Push the strands of the woof close together with the point of the needle. Repeat these operations until you have filled in the warp across the box. With a pair of scissors cut away the pasteboard and remove the piece of cloth. Bring this to school for inspection.

PROJECT III

HOW TO TEST CLOTHING MATERIALS

It is worth while to know a few simple tests for detecting frauds in clothing. "Guaranteed all wool" may be a mixture of cotton and wool fibers. Mercerized cotton and artificial silk may be substituted for real silk. "Real linen" may be a mixture of cotton and linen, or even all cotton.

Problems — 1. The flame tests and what they show.
2. How to test cloth fibers with chemicals.

Problem 1 — The flame tests and what they show

Class Problem. — Ignite with a match small pieces of wool, silk, cotton, linen, and artificial silk. Watch the flame in each test. Note carefully the odor given off by each kind of fiber as it burns. Examine the ash after each test. Arrange your results as follows:

Fiber Tested	Flame	Odor	Ash
Wool			
Silk			
Cotton			
Linen			
Artificial silk			

By these tests, you can easily distinguish wool and silk from cotton, linen, and artificial silk. How can you tell wool from silk? How can you tell artificial silk from cotton or linen? You will find it more difficult to distinguish cotton from linen by the flame test.

Home Problem. — Test at least four samples of cloth at home. Cut a two-inch square of each kind. First examine them carefully. Note the luster, feeling, and weight of each sample. Now pull each sample to pieces by raveling the threads each way of the cloth. Put the threads running one way of the cloth into one pile and the threads running the other way into a second pile. Test the threads in each pile by igniting them with a match flame. Watch them burn. Note carefully the flame, odor, and ash.

Glue a small sample of each cloth you test in your notebook or on a sheet of paper. Write neatly beside each sample the results of your tests.

Problem 2 — How to test cloth fibers with chemicals

Class Problem. — The following experiments should be performed by the teacher. Great care must be exercised to avoid spilling hot hydrochloric acid or lye on the skin or clothing.

(*a*) *How to tell real silk from artificial silk or mercerized cotton.* Boil a piece of real silk in concentrated hydrochloric acid for two or three minutes. What happens? Boil pieces of artificial silk and mercerized cotton in concentrated hydrochloric acid. What results do you get?

(*b*) *How to tell linen from cotton.* Boil small pieces of cotton and linen cloth in olive oil for about five minutes. Hold the pieces against a dark background and try to look through them. The cotton looks light, while the linen is dark.

(*c*) *How to tell wool from cotton.* Buy a small can of concentrated lye from a grocer. Put four heaping tablespoonfuls of this lye into a small agate kettle. Add a pint of water, and heat until it starts to boil. Drop into the lye

Hot lye dissolves wool but not cotton. Is this piece of cloth "all wool"?

a sample of clothing material, which you think is "all wool," and boil slowly for several minutes. Does the sample dissolve completely? If it does, it is all wool. If any of the sample does not dissolve, take it out of the kettle with a glass rod. This is probably cotton. Test other samples of cloth in the same way to determine whether they are composed of wool or cotton.

PROJECT IV

THE WASHING OF FABRICS

Our grandparents dreaded wash days. They scrubbed clothes by hand, rubbing them back and forth over a washboard. These primitive methods are still practiced to-day. In many homes, however, washing machines are used. These are operated by hand, water power, gas engines, or electric motors. Some washing machines churn the clothes in a rotating cylinder; others force water through them with vacuum cups.

Problems — 1. How to wash clothes.
2. How to make soap.
3. How to test water for washing.

Problem 1 — How to wash clothes

Class Problem. — How a washing machine works. Half fill a large glass jar with warm water. Add two tablespoonfuls of soap powder. Drop half a dozen soiled handkerchiefs into the jar. Now hold a large glass funnel, inverted, by the narrow stem. Push the wide mouth of the funnel under water, nearly to the bottom of the jar. Now raise the funnel quickly. *What happens?* Repeat several times. Explain why the funnel lifts up the water. How is water forced through the handkerchiefs? *Work the funnel up and down for several minutes.* Examine the handkerchiefs. How is the dirt removed? Why is this method of washing clothes better than scrubbing them on a washboard? Why do the clothes wear longer? Why is the dirt removed more quickly? Why are the clothes washed cleaner?

Home Problem. — How do you wash clothes at home? Do you use a washing machine? How does it work? How does it remove the dirt? Does it wash clothes clean? Do

To wash the clothes, move the funnel up and down. Some washing machines work in this way

you soak clothes overnight before you wash them? Do you use soap, washing powder, or ammonia? Explain why these help to remove the dirt.

Problem 2 — How to make soap

You can practice economy by making your own soap at home. Almost any kind of clean grease or tallow may be used. Save the fat from trimmings and cooked meats. All you need to buy is a can of lye from your grocer, and you are ready to make soap.

Class Problem. — For this experiment use a two-quart agate kettle, a pound can of Crisco, and a small can of concentrated lye. Use extreme care not to get any lye on the skin, for it causes severe burns.

Dissolve four heaping tablespoonfuls of lye in half a pint of cold water. Put the pound of Crisco into the agate kettle. Heat until the Crisco melts and becomes lukewarm. Now pour the lye solution into the melted Crisco

Pour the lye into the fat slowly and keep stirring

very slowly, in a tiny stream. Stir constantly with a large spoon. After all the lye solution has been added, continue stirring until the mass becomes thick and pasty. Pour into shallow plates and set them aside for at least a week. Cut the soap into small cakes and distribute among the members of the class.

Problem 3 — How to test water for washing

Rain water is soft. But when it soaks into the ground many kinds of mineral salts are usually dissolved, such as salts of lime and common table salt. Water from the ocean is very hard. This is also true of water from many wells and springs. Certain kinds of hard water can be softened

by boiling, other kinds can be softened by adding washing soda or borax. It is very difficult to wash with hard water. Soapsuds do not form in it. For this reason rain water must be used in some localities for cleansing purposes.

Class Problem. — How to test hard and soft water. Take three common drinking glasses. Half fill one glass with clear lime water. Half fill the other two glasses with rain water, and dissolve a spoonful of common table salt in one

Soft water makes better soapsuds than hard water

of them. Label the glasses: lime water, salt water, and rain water. Into each glass put a piece of ivory or castile soap, the size of a walnut. Now let three members of the class each hold one of the drinking glasses and cover the top with the hand. Shake vigorously for one or two minutes.

Examine the glasses. Which contains the best soapsuds, the lime water, salt water, or rain water? Is salt water hard or soft? Is rain water hard or soft? Hold each glass up to a window and let the light shine through the

water. What do you notice in the lime water? What are these little lumps? Why doesn't soap form suds in lime water? What becomes of the soap? Examine the salt water in the same manner. Do you find any little lumps in the glass of rain water? Which is the best water for washing clothes? Why?

Home Problem. — Test the water you use at home. Does it form good suds with soap? Is it hard or soft? Is it good water for washing clothes? Can it be improved in any way?

PROJECT V

HOME DYEING OF TEXTILES

Home dyeing is inexpensive. For a few cents you can brighten up many articles of clothing and other fabrics. It is also simple if you follow directions carefully. Use only standard dyes of reliable manufacture. No goods can be dyed a lighter color than the original shade. You cannot use some dyes over certain colors. For instance, do not try a red dye over blue or green. Follow directions on the package. All material must be washed thoroughly and spots removed before dyeing. There are two classes of fabrics which require two entirely different kinds of dyes — animal fiber fabrics and vegetable fiber fabrics. Wool and silk are animal fiber; cotton and linen are vegetable fiber.

Problems — 1. How to dye wool and silk.
2. How to dye cotton and linen.

Problem 1 — How to dye wool and silk

The directions given for the two following experiments are for Diamond Package Dyes. These may be purchased from any druggist or grocer. If you use other dyes follow directions given on the package.

Class Problem. — Bring from home pieces of white cloth made of woolen or silk materials. Open a package of dye such as is recommended to color wool or silk goods. Put half a teaspoonful of the powder into a small kettle. Use only tin, porcelain, or agate vessels for dyeing. Now add slowly a pint of boiling water. Boil for two or three minutes until the dye dissolves. Into a second kettle pour

a quart of warm water. Into this, strain through a cloth the contents of the first kettle. Add a tablespoonful of vinegar, and stir.

Now wash the cloth samples with soap and water. Rinse several times. Drop these into the dye solution in the

Strain through a piece of cloth

kettle. Boil slowly for about 30 minutes. Lift and stir constantly with two pieces of glass tubing. After boiling, rinse the pieces of cloth several times in cold water, and hang them up to dry. Glue a small sample of dyed material in your notebook to show the results of your experiment.

Problem 2 — How to dye cotton and linen

Class Problem. — For this experiment use pieces of white linen or cotton materials brought from home. Use a dye recommended for cotton and linen goods. Follow the direc-

tions that are given under Problem 1 with these two exceptions:

(*a*) Instead of a tablespoonful of vinegar add half a tablespoonful of common salt.

(*b*) After boiling, remove the kettle from the fire and stir the material for at least 15 minutes. For best results, stirring for half an hour is advised. Glue a small sample of dyed material in your notebook to show the results of your experiment.

PROJECT VI

THE REMOVAL OF SPOTS AND STAINS FROM CLOTHING

In order to keep our clothes neat and clean, we ought to know how to remove some of the grease spots and stains which are such a common cause of annoyance. If possible, stains should be removed while fresh. Colored goods and white goods frequently require different treatments. This is also true of cotton, wool, and silk. In many cases, warm water and soap is effective. If this fails, it may be necessary to use chemicals. The following chemicals are recommended as of special value in the removal of spots and stains. They may be purchased from any druggist and should be kept in every home.

Oxalic acid,	small bottle
Denatured alcohol,	half pint
Naphtha soap,	cake
Ammonia,	one pint
Carbona,	bottle
Javelle water,	one quart

Problems — 1. A list of common stains.
2. How to make Javelle water.
3. How spots and stains are removed.

Problem 1 — A list of common stains

Home Problem. — A few of the more common spots and stains are given in the following table, with the treatment for each. Copy this table for future reference. Directions for the removal of many other kinds of stains are given in Farmers' Bulletin 861, U. S. Department of Agriculture. You can get the bulletin, free, by asking for it.

Kind of Stain	Treatment
Sugar, glue, blood	Wash with warm water
Fruit and vegetable stains, and red ink	Warm soapsuds or Javelle water
Grass stains	Denatured alcohol or Javelle water
Iron rust	Oxalic acid
Black ink	Javelle water
Grease and oil	Naphtha soap or carbona
Paint, tar, and pitch	Carbona
Red acid stains	Ammonia and then wash thoroughly

Problem 2 — How to make Javelle water

Class Problem. — You can make Javelle water at home at a slight cost. It is a valuable bleaching agent, and also removes many kinds of stains. Do not use it on colored goods.

Dissolve one pound of common washing soda in a quart of hot water. Now dissolve a quarter of a pound of bleaching powder in a quart of lukewarm water. Mix the two

The bottle contains Javelle water. This is a good way to get the clear liquid without stirring up the sediment

solutions, and let it stand overnight. Pour off the clear liquid and bottle for future use. *This is Javelle water.*

How Javelle water bleaches. Pour a small quantity of Javelle water into a glass beaker. Drop in several samples of brightly colored cloth, and stir for several minutes. Remove the cloth samples and examine.

Problem 3 — How spots and stains are removed

Class Problem. — Demonstrate the removal of a few spots and stains.

Ammonia. Put several drops of strong hydrochloric acid on a piece of black cloth. Wait until the spots change to a red color. Now apply strong ammonia to the spots and wash thoroughly with water. What is the result?

Carbona. This is a liquid sold in bottles. It is one of the best solvents of grease, oil, fats, varnish, paints, etc. Carbona will not burn. In fact it puts out fire. For this reason it should be used in every home to take the place of dangerous explosives, such as ether, benzine, naphtha, or gasoline. *Try the action of carbona as follows:* Make a spot of grease, oil, or paint on a piece of white cloth. Wash it in a small quantity of carbona. Repeat, using clean liquid. Wash with soap and water.

Javelle water. Stain a white handkerchief with red ink. Soak it in Javelle water until the stains disappear. Rinse in warm water several times.

FACTS EVERY ONE SHOULD KNOW ABOUT CLOTHING

Many kinds of fibers are used for clothing, the principal ones being cotton, wool, linen, and silk.

Cotton. — Cotton comes from large oval pods, called bolls, the fruit of a plant. These bolls contain from thirty to forty seeds. Tufts of fine, white hairs cling to each seed, so that it may be carried away by the wind, in the same way that seeds of the dandelion and milkweed sail through the air by means of tiny parachutes of delicate hairs. When cotton bolls ripen, they burst open, and reveal a fluffy mass of snow-white cotton. After this cotton is picked by hand, it is sent to a mill, where a machine, called the cotton gin, separates the fibers from the seeds. These fibers are then pressed into big bales, weighing five hundred pounds or more, and shipped to great mills to be made into cloth.

Wool. — The thick, curly hair of the sheep, and some other animals, is called wool. Millions of sheep are raised in South America, Australia, and in the great western states of Idaho, Wyoming, and Montana. These sheep are usually clipped once a year and the wool is packed into large sacks, or bales, for shipment. This wool is very dirty and greasy. At the mill, it is first sorted into different grades, and then washed in long tanks with warm water and soap. The wool is then dried, combed or carded, and finally spun into yarn for weaving.

Linen. — Linen comes from the white bark layer of the flax plant. Examine the bark of a twig. You will find three layers: a thin corky layer on the outside, then a soft green layer, and a tough, fibrous, white layer next to the wood. It is this tough, fibrous layer of the flax plant that is used for making linen. Unlike cotton, flax grows in cold

countries, chiefly in Russia and Ireland. A field of growing flax is a beautiful sight, with its long slender stems and blue flowers. When mature, the plants are pulled up by the roots and laid in bundles. These are submerged in ponds or exposed to sun and rain for several weeks, until the stems partly decay. The stems are then passed through heavy rollers and crushed, so that the tough fibers of the bark can be separated from the rest of the stem. These fibers are cleaned, and then made into yarn for weaving linen cloth.

Silk. — Silk is produced by certain varieties of caterpillars, similar in appearance to those you have seen crawling along the branches of fruit trees. When fully grown, each caterpillar allows a yellowish liquid to ooze out from two little holes in the sides of its head. This liquid soon hardens into a fine elastic fiber, called silk. The caterpillar winds several thousand feet of this silk fiber around itself, making a *cocoon*, in which it slowly changes to a moth, with white wings and long legs. If these moths escape from the cocoons, the females lay eggs which hatch into caterpillars again. All butterflies and moths pass through these wonderful transformations during the different stages of their lives. The cocoons that are used for making silk are first subjected to great heat in order to kill the moths. Then the cocoons are soaked in hot water to soften them. The ends of the delicate silk fibers from four or five cocoons are joined and unwound from the cocoons to make a single thread of raw silk. About three thousand cocoons are required to make one pound of raw silk. This is coiled in skeins, and sold to manufacturers, to be made into cloth.

Weaving. — Weaving is a most interesting process. Whether it is done on the small hand loom of the Indians,

on the clumsy wooden device of colonial days, or on the wonderful Jacquard power loom of to-day, the principles are much the same. Many parallel warp threads are held close together by a frame. These threads are separated into two or more layers. Woof thread is wound on bobbins. Each time the shuttle, carrying a bobbin, passes back or forth between these layers, alternate warp threads are crossed, by being raised or lowered. This binds all the threads firmly together. You will notice how cloth is woven, if you unravel a small piece. The crossing and recrossing of the warp threads are clearly shown.

It is most interesting to make a collection of cloth samples, and glue them in your notebook. You will find many different kinds of cloth made with different weaves, patterns, finish, and materials. *How many of the following kinds of cloth do you know?* What is the cost per yard of each kind? For what purposes is each kind of cloth used?

A Few Common Kinds of Clothing Materials

Cotton

Batiste (cotton)	Gingham	Nainsook
Calico	Galatea	Organdie
Cambric (cotton)	Khaki	Percale
Cheesecloth	Lawn	Sateen
Cretonne	Madras	Scrim
Denim	Muslin	Velveteen
Damask (cotton)		

Wool

Blankets	Cheviot	Panama
Brilliantine	Flannel (wool)	Serge
Broadcloth	Grenadine	Tweed
Bunting	Mohair	Venetian
Cashmere	Nun's veiling	Voile

Linen

Batiste (linen)	Crash	Huckaback
Butcher's linen	Damask (linen)	Linen lawn
Cambric (linen)		

Silk

Chiffon	Maline	Satin
China silk	Pongee	Taffeta
Crêpe de chine	Plush	Tulle
Foulard	Rajah	Velvet
Moire		

These clothing materials are used for many different purposes. They vary greatly in cost, wearing qualities, weight, texture, appearance, warmth, resistance to moisture, etc. Organdie costs more than calico, tweed costs more than cheviot, and velvet is more expensive than taffeta. Galatea and denim wear longer than muslin or lawn. Khaki is much heavier than percale, and serge than voile. Cheesecloth and scrim are woven loosely. Galatea and khaki are woven closely and firmly. Brilliantine is hard and shiny. Cashmere is soft and dull. Flannel and serge are much warmer than crêpe de chine or gingham. Cambric and calico wet through quicker than cashmere or tweed. All these varying characteristics must be considered when you buy clothing materials. Garments made of wool are warmer than those made of cotton, linen, or silk. Woolen cloth is woven loosely and there are many little air spaces between the fibers. For this reason it conducts heat away from the body slowly, and keeps us warm. Woolen blankets feel warmer than those made of cotton or linen. Cotton and linen conduct heat away from the body rapidly and make us feel cold. This also explains why underwear made of cotton, linen, or silk is cool in summer. These materials are good conductors of heat.

Dip a woolen rag into a basin of water. Notice how slowly it wets through. Now experiment with rags made of cotton, linen, and silk. They absorb water very quickly.

Woolen garments are therefore a better protection to the body in damp or stormy weather. On the other hand, garments made of cotton, linen, or silk dry quicker than woolen ones. Have you noticed that a woolen bathing suit feels warmer than a cotton one when wet? Water absorbs heat when it evaporates, and the faster evaporation takes place the faster heat is absorbed. Now a cotton bathing suit dries faster than a woolen one. Evaporation takes place faster. Therefore heat is taken away from the body faster, and we feel colder. These peculiarities increase the desirability of cotton, linen, or silk underwear in summer. These materials absorb perspiration from the skin quickly. The perspiration evaporates quickly and absorbs heat from the body, thus keeping us cool.

Tests for Adulteration. — When you buy clothing materials, watch out for adulterations or substitutions. You want what you pay for. If you pay for "all wool," you do not want cloth which is half cotton. If you pay for "pure silk," you want "pure silk," and not artificial silk or mercerized cotton. If you pay for "pure linen," you do not want all cotton, or a mixture of cotton and linen. A few simple tests will help to protect you against thsee frauds.

The burning tests are the easiest to apply. Cotton fibers burn very quickly, with a bright yellow flame, giving off the odor of burning wood and leaving a fine gray ash. Mercerized cotton and artificial silk burn in much the same way. Wool fibers burn slowly, with a flickering flame, giving off the odor of burnt hair, and leaving a hard black substance. Silk fibers burn somewhat like wool, but they

burn quicker, with a blue flame, and the odor of burning hair is not as disagreeable. Linen fibers burn quickly, with a bright yellow flame, giving off the odor of burning wood and leaving a fine gray ash. By the burning test, you can easily tell wool from cotton or linen. You can also tell pure silk from mercerized cotton or artificial silk. You will find it more difficult to tell cotton from linen. For this, you can examine the fibers under a microscope or you can use certain chemicals. You will find that hydrochloric acid dissolves silk, and caustic potash or lye dissolves wool and silk.

The appearance and feeling of the fabrics will tell you many things. Woolen cloth is usually soft and springy, with stiff, curly fibers. Silk is smooth and glossy, with long, strong, straight fibers. Linen is hard and smooth, with stiff, strong, slippery fibers. Cotton is soft and pliable, with short fibers which " fuzz out " at the ends.

It is impossible for all of us to buy expensive clothes, but we can keep those we do wear neat and clean. We can keep them well pressed. We can wash them with soap and water. We can dye old materials and make them over. We can remove untidy looking spots and stains. By taking good care of our clothes, they will look better and wear longer.

Washing Clothes. — When you wash clothes, use soft water. This makes better soapsuds and dissolves the dirt quicker. Do not use lye, caustic soda, or strong washing powders. These destroy the fibers of wool and silk by dissolving them. It is a good plan to soak clothes before washing them, as this helps to loosen the dirt, so that it is removed more easily. Do not soak colored fabrics. Wash them quickly in lukewarm water and soap, and wring very dry. Then hang them in the shade to dry. Do not rub

delicate silk fabrics. Slosh them up and down in lukewarm water and soapsuds, then rinse in lukewarm water. Press out the water gently between dry towels. Press while damp with a moderately hot iron. Woolen fabrics are washed the same as silk, in lukewarm water. Do not rub or twist them. Dry in a warm place, but not in the sun. Do not hang heavy woolens on a line. It pulls them out of shape. White cotton or linen fabrics should be dried in the sun, as this helps to whiten and sterilize them.

Dyeing. — It is not necessary to be an expert chemist, in order to dye clothing materials. Simply buy a package of dye. Full directions are given on the package. Follow these carefully. It is a good plan, however, to observe the following cautions. Wool and silk are animal fibers. Cotton and linen are vegetable fibers. For this reason they require different treatments. A dye intended for wool or silk cannot be used on cotton or linen. Wash and rinse the material thoroughly before dyeing. White fabrics can be dyed very easily and satisfactorily. It is more difficult to dye colored fabrics. You can dye them the same color, or certain darker shades, but not lighter. Some combinations of colors produce peculiar and unexpected results. For these reasons it is always a good plan to experiment with a small sample first.

Removing Stains. — You can remove stains from clothing by four methods. Some may be dissolved, some absorbed, some bleached, and others neutralized. Blood, coffee, tea, or fruit stains may be dissolved and removed with cold or hot water. Grass stains are dissolved by alcohol. Grease, oil, paint, or tar may be removed by turpentine or benzine, but carbona is much safer to use, because it does not burn.

Some stains may be absorbed and removed by starch paste, French chalk, or lard. Instead of using carbona, you can cover grease spots with French chalk. Hold a hot iron over them, and brush off. Cover blood stains or scorch with starch paste. Let them dry and brush off. Cover spots of tar or oil with lard. Let them stand several hours, and wash with soap and water. Javelle water removes many stains, such as rust, ink, perspiration, grass, mildew, or fruit. The stains are "bleached out." Do not use Javelle water on colored goods. Acid stains usually turn red. You can remove these with a weak alkali, such as ammonia and water. It is much easier to remove fresh stains than old ones. Try warm water and soap before using chemicals. Take care not to spread the stain. Don't spoil expensive garments. Send them to a professional cleanser.

Select your clothes carefully, with regard to health and comfort. Do not choose extreme styles, or "loud" colors. They make you look cheap. Keep your clothes well pressed. Change your underwear frequently. Do not wear heavy woolen underwear indoors. It makes you more sensitive to cold when you go out. Keep your clothes neat and clean. By exercising care and good judgment in regard to your clothes, you will not only look better, but you will feel better.

CHAPTER X

THE WORLD OF LITTLE THINGS

Of all living things that inhabit the earth, whether plants or animals, the great majority are invisible. They are so small that you cannot see them with the naked eye. These exceedingly minute organisms live and grow almost everywhere. A drop of dirty water, or a drop of old milk, may contain millions.

Many tiny plants live and grow, all the time, in your mouth, nose, and intestines. Many float about in the air. You inhale some of these with every breath. Many are constantly present on your hair and skin. Many more are swallowed when you eat and drink.

Some of these tiny plants are useful. They raise bread, flavor butter and cheese, make vinegar, or help to increase the fertility of the soil. Others are harmful. They ferment preserves, sour milk, spoil foods, or cause serious diseases, such as tuberculosis, influenza, typhoid fever, and diphtheria.

In the following chapter, we want you to raise some of these tiny plants and study them. We want you to find out what these tiny plants are, what they look like, how they grow, what they do, and how they affect our daily living.

PROJECT I

THE WORK OF YEAST PLANTS

Problems — 1. A yeast cake and how it acts.
2. How yeast plants multiply.
3. Where yeast comes from.
4. How yeast plants grow under different conditions.
5. How bread is "raised."

Problem 1 — A yeast cake and how it acts

Home Problem. — Put two tablespoonfuls of honey, molasses, or sirup into a drinking glass. Dissolve quarter of a yeast cake in a little warm water and pour into the glass. Fill to the brim with lukewarm water. Partly fill a shallow soup plate with warm water. Place a cardboard over the top of the glass and tip it upside down into the water in the plate. Don't let any liquid come out of the glass. Set the plate on a radiator or near a stove, where it will keep warm.

Examine the following morning. What has happened? Why did the solution come out of the glass? Is the glass empty? Put a cardboard under the glass. Raise it quickly and set it upright. Thrust a burning match into the glass. What does this show? Describe the odor of the liquid in the plate. What does it contain?

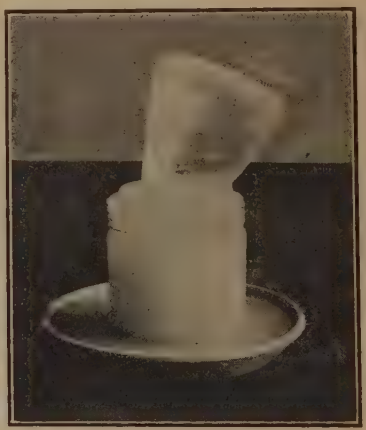
When yeasts act on sweetened liquids, the liquids are said to *ferment.*

Class Problem. — Put three tablespoonfuls of molasses into an Erlenmeyer flask which holds about a pint. Dissolve half a yeast cake in a cup of warm water. Pour

into the flask. Fill with warm water. Invert the flask and set it in a quart battery jar.

Examine the following morning. What happened to the liquid in the flask? Where is it now? Why did it go out of the flask? Put one hand over the mouth of the flask and set it upright. Insert a two-hole rubber stopper. Fit a long-stemmed thistle tube in one hole. In the other, fit a short piece of glass tubing bent at right angles. Connect

This flask is filled with water, sirup, and yeast



The same flask 24 hours later. Where is the liquid? What is in the flask?

a piece of rubber tubing. Select two small bottles with wide mouths. Fill with water and invert in a shallow basin of water. Transfer the gas in the flask to the bottles, by pouring water down the thistle tube. Into one bottle thrust a blazing splint. What happens? Into the second bottle pour a small quantity of clear lime water. What is the result?

What gas is produced when yeast plants grow in a solution of molasses and water? What gas is formed when sweetened liquids ferment? Why does home-made root

beer " pop " when you open a bottle? *Examine the liquid in the jar.* Does it smell like molasses? Heat about half a pint in a simple still and catch a few drops of the first liquid that comes over. Pour this on a plate and ignite

Transfer the gas from the flask to clean bottles

with a match. Watch it burn. What color is the flame? What is this liquid? How is alcohol obtained? What happens to sugar when it ferments?

Problem 2 — How yeast plants multiply

Yeasts are plants, so tiny that you cannot see them with the naked eye. They are composed of single cells. These plants multiply by putting out little projections (buds) from the larger cells. Some of these buds break off and grow to full-sized cells.

Class Problem. — Examine yeast plants under a compound

microscope. Take these from the jar of fermented liquid that you used in the preceding problem. You will notice a white scum floating on the surface of the liquid in the jar. Transfer a drop of this white scum to a glass slide. Put on a cover glass and examine under the microscope. Use both low and high power. Notice the clusters of yeast plants, the oval cells, and the tiny buds. Draw what you see. What is a yeast cake? Why are some yeast cakes worthless?

Under a microscope yeast plants look like this. Notice how the old plants produce new ones

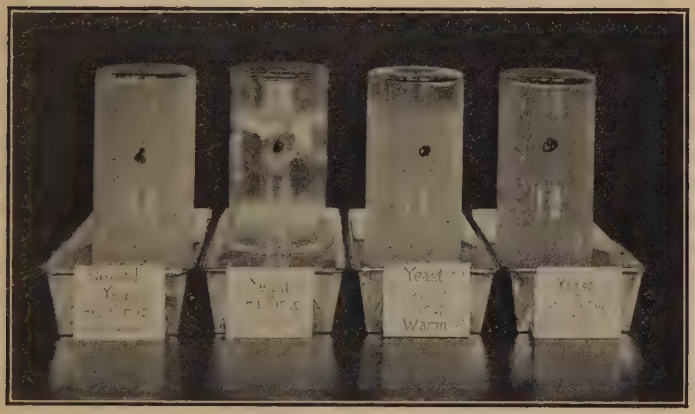
Problem 3 — Where yeast comes from

Home Problem. — Put half a cupful of finely chopped raisins into each of two preserving jars, pint size. Fill both jars with warm water. Put on the covers, but do not clamp them down. Set the jars in a large kettle on several narrow strips of wood. Pour about three inches of water into the kettle and put on the cover. Set the kettle on the stove and let the water boil for one hour. Clamp the glass cover of one jar down tightly. Remove the cover from the second jar.

Set both jars in a warm place for about a week. Look at them occasionally. Does the liquid in the closed jar ferment? What happens to the liquid in the open jar? This fermentation is caused by yeast plants. *Where do these yeast plants come from?*

Problem 4 — How yeast plants grow under different conditions

Class Problem. — Take four drinking glasses. Label them No. 1, No. 2, No. 3, and No. 4. Divide a yeast cake into quarters. Boil one quarter of the yeast cake in half a cup of water, for three or four minutes. Let this cool, and pour it into glass No. 1. Dissolve each of the other



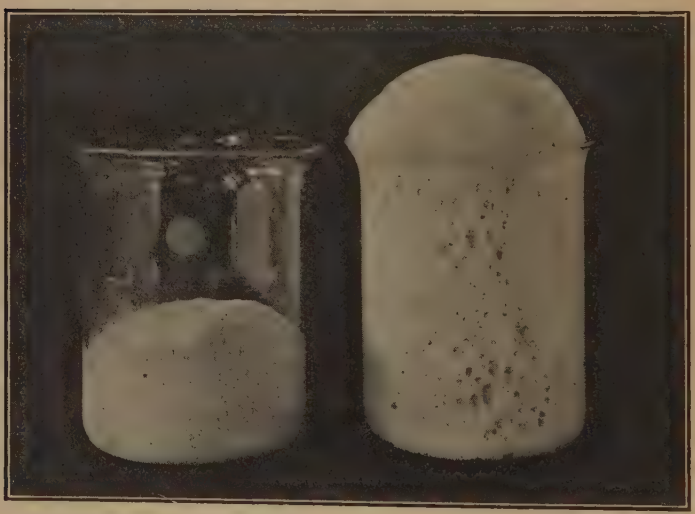
What are the best conditions for the growth of yeast?

quarters in a little water, and pour into glasses No. 2, No. 3, and No. 4. Put two teaspoonfuls of Karo Corn Sirup into glasses No. 1, No. 2, and No. 4, but no sirup in glass No. 3. Fill glasses No. 1, No. 2, and No. 3 with warm water. Fill glass No. 4 with ice water. Partly fill four soup plates with water. Pour warm water into three of the plates, and ice water into the fourth. Place cardboards over the glasses and invert them into the water in the soup plates. Invert glass No. 4 into the ice water. Set the soup plates containing glasses No. 1, No. 2, and No. 3 in a warm place. Set the remaining soup plate where it is cold.

Examine the following morning. Did the liquid in glass No. 1 ferment? In glass No. 3? In glass No. 4? Explain in each case why the liquids failed to ferment. Did the liquid in glass No. 2 ferment? Explain. What conditions favor the growth of yeast plants? What conditions are unfavorable to this growth?

Problem 5 — How bread is "raised"

Home Problem. — Examine a slice of bread. What are the holes? Why do you "raise" bread? Why do you



The same amount of dough was put into each beaker. One batch of dough contains yeast; the other does not

mix sugar with the dough? What becomes of the yeast when bread is baked? Of the alcohol?

Class Problem. — Take two glass jars. Label them No. 1 and No. 2. Put a handful of white flour and a teaspoonful of sugar into each jar. Dissolve quarter of a yeast cake in a little warm water and pour it into jar No. 1. Do not

put any yeast in jar No. 2. Add lukewarm water to both jars, and mix, making a stiff dough. Set the jars away in a warm place.

Examine the following morning. Did the dough in jar No. 1 rise? Notice the bubbles. What are these bubbles? What prevents the gas from escaping? Taste a little of the dough. Describe the taste. Can you taste any sugar? *Did the dough in jar No. 2 rise?* How do you account for this?

Why do you set dough in a warm place to rise? Why do you use a fresh yeast cake? Why do you dissolve the yeast in warm water rather than boiling water?

PROJECT II

THE WORK OF MOLDS

Problems — 1. Where molds come from.
2. Raising a crop of bread mold.
3. How molds multiply.
4. How molds grow under different conditions.
5. How different kinds of molds act.

Problem 1 — Where molds come from

Home Problem. — Lay about a dozen thicknesses of newspaper in the bottom of a saucer. Wet them thoroughly

A slice of bread planted with mold spores

with warm water. On these lay a slice of bread. Find a shelf covered with dust. Blow some of this dust on the bread. Cover with another saucer and set away in a warm dark place for a week or more. Add a few drops of warm

water each day if necessary to keep the bread moist. Does the bread become moldy? Where do these molds come from? Take your slice of bread to school to show the results of your experiment.

Problem 2 — Raising a crop of bread mold

Class Problem. — Take a large plate. Lay several thicknesses of blotting paper in it, and wet thoroughly with warm water. Lay a thick slice of bread on the blotting

The same slice of bread three days later

paper. From the crops raised at home, take a slice of bread covered with a good growth of black mold. With the finger tips, touch this mold and then the slice of bread. Repeat several times.

Cover the bread with a large glass jar, and set it away in a warm dark closet. Add a few drops of warm water each day to keep the bread moist. After a few days,

examine the slice of bread. What do you find? Describe the mold. Notice the odor of the bread. Is it good to eat?

Problem 3 — How molds multiply

Class Problem. — Examine the bread mold that you raised in the preceding problem. Describe it. What color are the slender threads? Do they contain any of the green substance, called chlorophyll, such as you find in the leaves of trees? Molds cannot manufacture their own foods. Where do they get them? How do they differ in this respect from plants with green leaves, such as the nasturtium?

Examine the bread mold closely for tiny black balls. These balls are filled with microscopic bodies, called spores, which

Growing mold plants much enlarged. The round balls are filled with tiny spores

take the place of seeds. How can molds grow from dust particles?

Examine some of the white threads, black balls, and spores under a compound microscope. Use both high and low power. Make neat drawings to show how these parts look.

Problem 4 — How molds grow under different conditions

Class Problem. — Take three large plates. Lay two or three thicknesses of blotting paper in each. Wet the blotting paper in two of the plates. Cut three slices of bread. Place one slice in a warm oven until it is thoroughly dry. Lay this on the dry blotting paper. Lay the other two slices on the wet blotting paper, one in each plate.

Take bread covered with a good growth of black mold. With the finger tips touch the mold and then a slice of bread. Repeat several times for each slice. Now cover each slice of bread with a large glass jar. Set one of the plates, with wet blotting paper, in a sunny window. Set the other two plates in a warm dark closet. Keep the wet blotting paper wet, by adding a few drops of water each day.

Notice the three slices of bread occasionally, for a week or ten days. Do molds grow better in darkness or in sunlight? With moisture or without moisture? Cold retards the growth of mold, while warmth quickens it.

Explain why dried foods, such as beans, flour, crackers, evaporated apples, and raisins, keep so well. Why is it necessary to wash out your bread tins frequently in summer? Why do some people set these tins in the sun to dry? Why do fruits and vegetables keep better in a dry, cool place? Why are lemons, oranges, and other kinds of fruit wrapped in tissue paper when they are packed for the market?

Problem 5 — How different kinds of molds act

Home Problem. — Where have you seen molds or mildews growing? They are very common on the following materials. Examine the list given at the top of page 346. How do molds or mildews affect these materials?

Oranges	Bread	Pickles	Decayed wood
Lemons	Pie	Shoes	Rubbish piles
Apples	Cake	Clothing	Horse manure
Potatoes	Cheese	Hay	Black soil
Meat	Cream	Dead leaves	

Give one reason why fruits and vegetables decay. Why do bread and pastry spoil? How do molds affect cheese? Have you seen mold or mildew growing on old shoes or damp clothing in summer? What is the cause of this? Have you seen mold in rotting leaves, horse manure, piles of damp rubbish, and wood? Does this show one reason for their decay? Is this of any benefit to the soil? What is humus? How is it formed? Explain how molds help to feed us.

PROJECT III

BACTERIA AND WHAT THEY ARE

Problems — 1. The size of bacteria.
2. The different forms of bacteria.
3. How bacteria multiply.

Problem 1 — The size of bacteria

Home Problem. — Determine the size of the smallest object you can see with the naked eye, as follows: Take a lead pencil with a very sharp point. Make two dots on a sheet of paper, just one-sixteenth of an inch apart. Fill in the space between these two dots with tiny pencil dots that are barely visible. Place the dots side by side, so that they just touch one another. Count the number of pencil dots. How big is each dot?

Bacteria are measured in microns. There are one thousand microns in a millimeter, and twenty-five millimeters in an inch. How many microns are there in an inch?

Some bacteria measure about one micron in length. How many of these bacteria, placed end to end, would it take to stretch across a pencil dot? Across an inch? How large will these bacteria appear to be under a compound microscope that magnifies them one thousand times? How large would you be if magnified one thousand times?

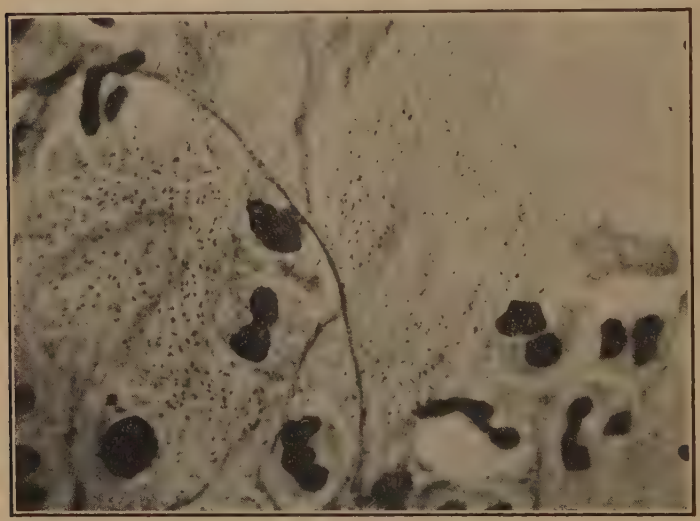
Problem 2 — The different forms of bacteria

Bacteria are the simplest of all living things. They consist of a single cell — a thin skin or membrane filled with a jelly-like substance, called *protoplasm.* They absorb liquid foods through this skin, and throw off waste materials in the same way. Delicate hairs, called cilia, are attached

to some bacteria. These enable them to swim about in liquids. There are many different kinds of bacteria, but most of them are rod-shaped, ball-shaped, or spiral-shaped.

Home Problem.— With the fingers, work small pieces of moist bread into different shapes. Make models to illustrate the three forms of bacteria, as follows:

Rod-shaped Bacteria. Model a small piece of bread into the shape of a sausage. Call this a *bacillus*. Bacteria

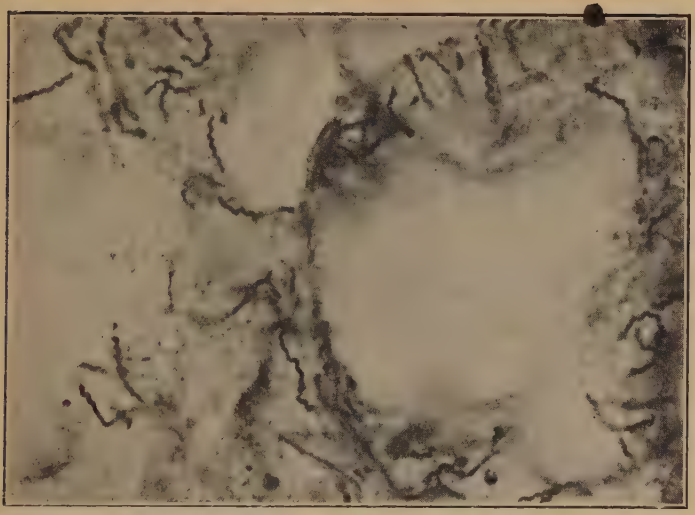


Notice the tiny dots, smaller than a pin head. These are bacilli which cause influenza. The picture shows them one thousand times as long as they actually are

Courtesy of Dr. Wm. H. Smith. Photo by L. S. Brown, Massachusetts General Hospital

that cause such diseases as tuberculosis, typhoid fever, and diphtheria are shaped like this.

Ball-shaped Bacteria. Model a small piece of bread into the shape of a marble. Call this a *coccus*. Bacteria that cause pneumonia, boils, and blood poisoning are of this shape.



Spirochaeta pallida, magnified 1000 times. These spiral organisms cause one of the most dreaded of all human diseases

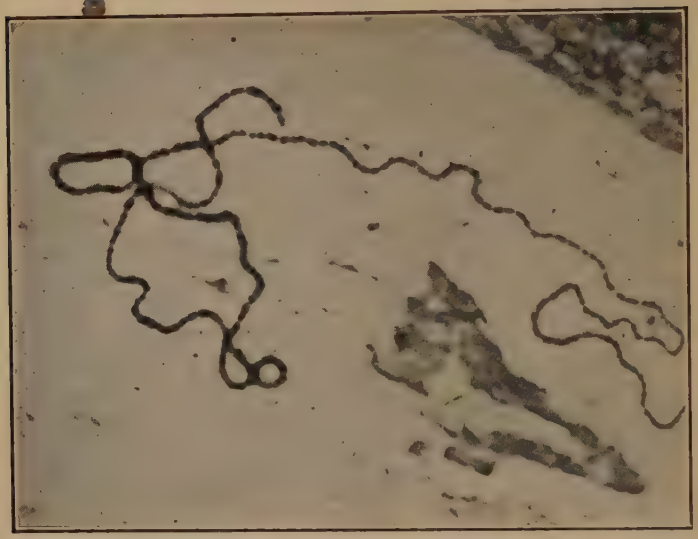
Courtesy of Dr. H. F. Hartwell. Photo by L. S. Brown, Massachusetts General Hospital

Spiral-shaped Bacteria. Some sausages are not straight. They are curved or bent. Model a small piece of bread into this shape. Call this a *spirillum.* The terrible disease known as Asiatic cholera is caused by a *spirillum.*

Problem 3 — How bacteria multiply

Bacteria do not lay eggs, or produce seeds. They multiply by splitting in two, crosswise. Delicate membranes divide the full-grown mother cell into two equal smaller cells. There are then two bacteria instead of one. These grow and again split in two. This process continues indefinitely. It sometimes takes about an hour for the division to take place.

Home Problem. — Suppose you swallow a single bacterium of typhoid fever at twelve o'clock noon. If con-



Streptococcus, magnified 1500 times. This long chain was produced from a single coccus by repeated divisions

Courtesy of Dr. Wm. H. Smith. Photo by L. S. Brown, Massachusetts General Hospital

ditions are favorable, how many typhoid bacteria may be present in your system at one o'clock? At two o'clock? At three o'clock? At twelve o'clock the following day? Determine the total number of typhoid bacteria that may develop in a single day of twenty-four hours. Arrange your results as follows:

Time	No. of Bacteria
12 o'clock (noon)	1
1 o'clock	2
2 o'clock	4
3 o'clock, etc.	8, etc.

When you catch a disease, such as typhoid fever, measles, scarlet fever, or diphtheria, it takes several days before you begin to feel sick. What is the reason for this?

PROJECT IV

THE WORK OF BACTERIA

Many kinds of bacteria perform valuable services for man. They give the delicate flavors to butter, change apple cider into vinegar, ferment sourcrout, clean up filth, or produce foods that plants need for growth. *Other kinds of bacteria are our foes*, spoiling foods or causing diseases.

Problems — 1. How foods are spoiled by bacteria.
2. A study of common diseases.

Problem 1 — How foods are spoiled by bacteria

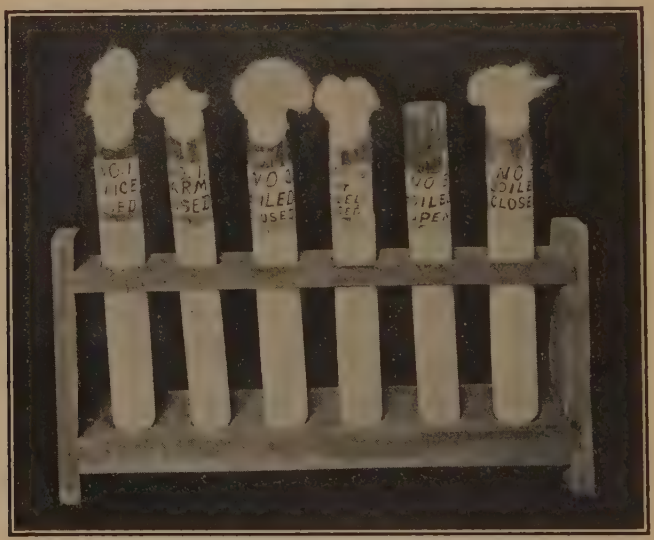
Class Problem. — Take a bottle of fresh milk and shake up the cream. Place six clean test tubes in a rack. Fill each about two-thirds full of milk. Pour three or four inches of water into a coffee can and set three of the tubes into it. Heat, letting the water boil slowly for ten minutes. Plug all the tubes with a wad of cotton, except one of those containing boiled milk. Arrange them in pairs and label as follows:

No. 1 On ice Closed	No. 2 Boiled Closed	No. 3 Boiled Open
No. 1 Warm Closed	No. 2 Not Boiled Closed	No. 3 Boiled Closed

Put one of the tubes, labeled No. 1, on ice. Set the rack with the others near a warm radiator or stove.

Examine each day for about a week. In which of the tubes labeled No. 1 does the milk sour first? What is the reason for this? Explain why food keeps longer on ice.

Compare the tubes labeled No. 2. In which does the milk sour first? Explain. What is pasteurized milk? Why does it keep longer? Why is it safer to use?

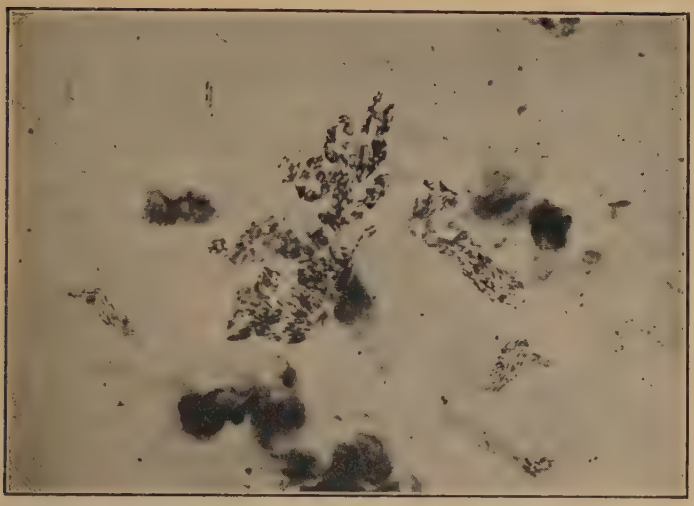


In which tubes does the milk sour first? Why?

Compare the tubes labeled No. 3. In which does the milk sour first? What is the reason for this? Explain the advantages of keeping food covered.

Problem 2 — A study of common diseases

Home Problem. — Study the list of common diseases given below. Which of these diseases cause the most deaths in your locality? What means are taken by your Board of Health officials to check them? Have you ever been vaccinated for smallpox? What is the purpose of



The clusters of tiny black dots are the bacilli of tuberculosis. They cause thousands of deaths every year

Courtesy of Dr. Wm. H. Smith. Photo by L. S. Brown, Massachusetts General Hospital

this? How is it done? What is an antitoxin? How is it applied? *Have you ever had any of the following diseases?* How did you "catch them"? How did these diseases affect you? How were you treated by the doctor? Can you have the same diseases again?

LIST OF COMMON DISEASES

Colds	Malaria	Yellow fever
Tuberculosis	Typhoid fever	Scarlet fever
Pneumonia	Dysentery	Lockjaw
Influenza	Measles	Blood poisoning
Diphtheria	Smallpox	Anthrax
Whooping cough	Chicken pox	Erysipelas
Tonsillitis	Mumps	Leprosy
Typhus fever	Infantile paralysis	Hydrophobia

PROJECT V

BACTERIA GARDENS AND WHAT THEY SHOW

The best way to study bacteria is to raise them in glass gardens, called *Petri dishes*. In these gardens, the bacteria grow in clusters, which you can see very distinctly with the naked eye. Each cluster is called a colony and consists of millions of bacteria, all piled together.

Problems —
1. How to prepare bacteria gardens.
2. How dust carries diseases.
3. Clean hands and dirty hands.
4. How the house fly carries diseases.
5. Why coughing is dangerous.
6. How our teeth decay.
7. Bacteria in drinking water.
8. Bacteria in milk.

Problem 1 — How to prepare bacteria gardens

Teacher's Problem. — (*a*) Place a dozen Petri dishes in the oven of a gas or coal range. Close the oven door. Heat the dishes very hot for about two hours, to kill all the bacteria they may contain. Let the oven cool. Remove the Petri dishes, taking care not to raise the glass covers. These dishes are now *sterilized*, and ready to use.

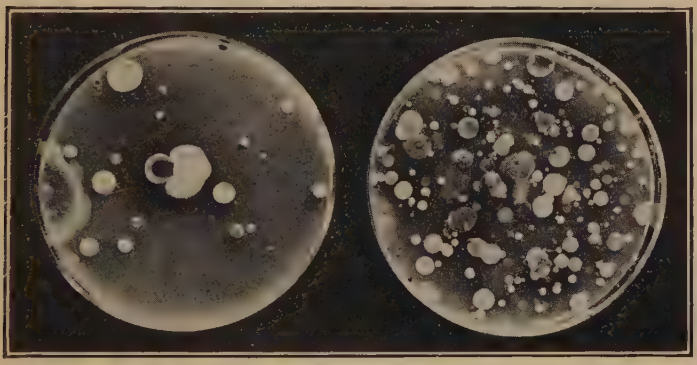
(*b*) In order to grow, bacteria must have food, like other plants. The most satisfactory food to use for these glass gardens is *nutrient agar*. Prepare this as follows:

Peel three medium sized potatoes. Wash. Cut in slices. Boil in one quart of water for ten minutes. Without moving the potatoes, drain off one pint of water. Strain this through a fine white cloth. Stir in half an ounce of *agar*, cut in small pieces. Let stand for ten minutes; then heat until the agar is thoroughly

dissolved. Strain again. Pour into test tubes, filling them about half full. Plug each tube with a wad of cotton batting. Stand the tubes of agar in a coffee can containing about three inches of water. Boil slowly for half an hour. The agar is now sterilized and ready for use in the following problems.

Problem 2 — How dust carries diseases

Class Problem. — Place two sterilized Petri dishes on the table. Set two tubes of nutrient agar into a can of



This dish was exposed three minutes before dusting

This dish was exposed one minute after dusting

Each spot is a cluster of millions of bacteria

water and heat until the hardened agar is changed to a liquid. Pour the agar into the two Petri dishes. In pouring, exercise great care. First burn the top of the cotton wad with a match flame. Remove the wad. Raise one side of the glass cover. Pour quickly and carefully. Lower the cover immediately. Let the Petri dishes stand for five minutes, until the agar hardens again.

Plant the two bacteria gardens as follows: Remove the cover from one Petri dish for two minutes. Put the cover on again. Label this dish, *No. 1, Before dusting.*

Now dust the desks and tables of the classroom with dry cloths. Shake the cloths occasionally. Remove the cover from the second Petri dish, for two minutes. Label this dish, *No. 2, After dusting.* Set both Petri dishes away in a warm, dark place.

Examine the two dishes at the end of three or four days. Notice the clusters or colonies of bacteria. Some of the colonies may be molds. You can tell them from the colonies of bacteria, because they are composed of many tiny white threads.

Each colony of bacteria probably started from a single bacterium. Notice the different colors, sizes, shapes, and margins of the colonies. What does this show? Where did these bacteria come from? Why are the colonies visible? Can you see the bacteria themselves? Why did you place the Petri dishes in a warm, dark place for several days? *Compare the number of colonies in each dish.* How do you account for this? Can dust carry disease germs? What is the safest method to dust a room? Why are vacuum cleaners better than brooms?

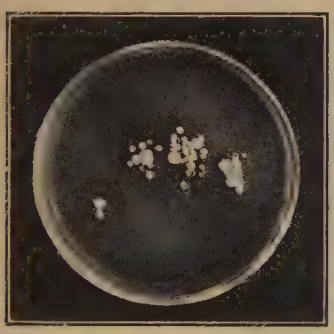
Problem 3 — Clean hands and dirty hands

Class Problem. — Pour agar into two sterilized Petri dishes, as directed in the previous problem. Let this agar harden.

Plant these two bacteria gardens as follows: Raise the glass cover of one dish, and touch the surface of the agar gently with the finger tips. Put the cover on again. Label this dish, *No. 1, Dirty hands.* Now wash your hands thoroughly with soap and water, scrubbing them well with a brush, and dry them on a clean towel. Raise the cover of the second Petri dish, and touch the surface of the agar gently with the finger tips. Put this cover on

again. Label the second dish, *No. 2, Clean hands.* Set both Petri dishes away in a warm, dark place.

Examine at the end of three or four days. Notice the colonies of bacteria. Describe them. Where did these



A boy touched the agar in this dish with the tips of his dirty fingers

After cleaning his fingers thoroughly the boy touched the agar in this dish

Clean hands are safer than dirty hands

colonies come from? Why are they visible? How many kinds of bacteria can you find? *Compare the number of colonies in each dish.* Explain. Where are more bacteria present, on clean hands or dirty hands? Do you wash your hands before you eat or handle food? Why is this the safest plan? Can dirty hands spread dangerous diseases?

Problem 4 — How the house fly carries diseases

Class Problem. — Pour agar into a sterilized Petri dish and let it harden.

Plant this garden as follows: Catch a house fly. Raise one edge of the glass cover and drop the fly into the Petri dish. Let the fly walk across the surface of the agar several times and then release it. Label. Set the Petri dish away in a warm, dark place.

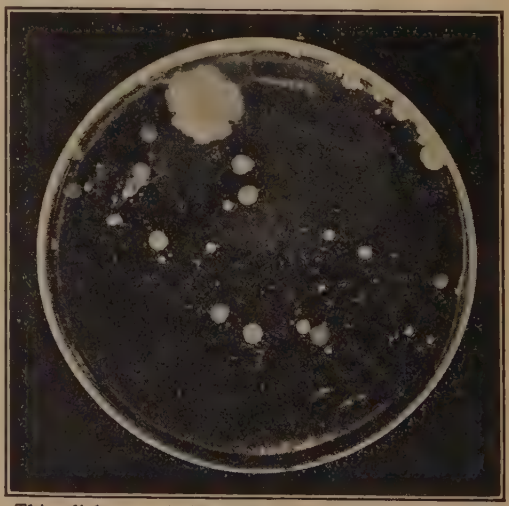
A fly walked across the agar in this dish. Wherever his feet touched the agar he left bacteria

Examine at the end of three or four days. Notice the colonies of bacteria. How many kinds do you find? Where did these bacteria come from? Where do flies breed? How do flies carry disease germs? Do you have flies at home? How do you destroy them?

Problem 5 — Why coughing is dangerous

Class Problem. — Pour agar into a sterilized Petri dish and let it harden.

Plant this garden as follows: Remove the glass cover. Hold the open dish about one foot away from your face, and cough or sneeze several times



This dish was held a foot from a boy's face while he was sneezing. Notice the colonies of bacteria

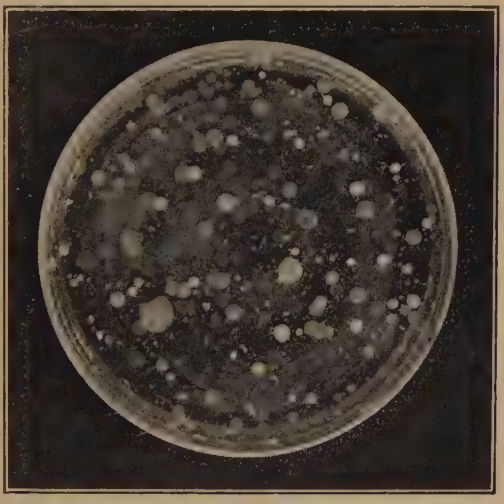
directly at it. Label. Set the dish away in a warm, dark place.

Examine at the end of three or four days. Notice the colonies of bacteria. How many kinds do you find? Where did these bacteria come from? Can coughing or sneezing spread colds, pneumonia, tuberculosis, and other diseases? *How?* What is the safest way to cough or sneeze? Why do you use a handkerchief? Do you carry dirty handkerchiefs in your pocket? Why is this a dangerous practice?

Problem 6 — How our teeth decay

Class Problem. — Pour agar into a sterilized Petri dish and let it harden.

Pull out a single strand of iron picture cord wire, about three inches long. Make a loop in one end of the wire, about one-eighth of an inch in diameter. Heat the wire loop red hot and then let it cool. Find some one in the class who has a partly decayed tooth. Place the wire loop in the cavity of the tooth and remove a loop full of material. Now raise the cover of the Petri dish. Touch the surface of the agar in a dozen or more places with the wire loop. Label. Set the dish away in a warm, dark place.

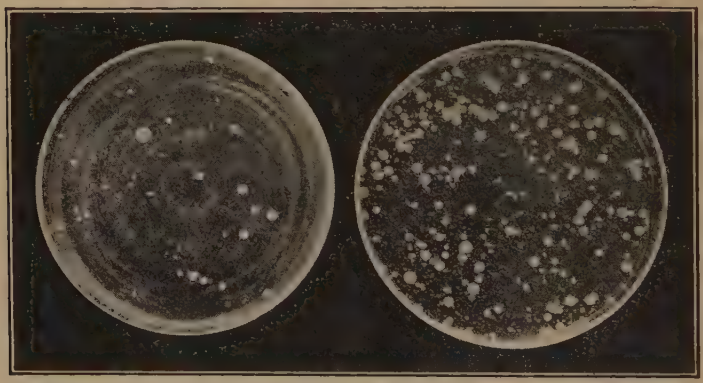


The bacteria planted in this garden came from the end of a fine wire which had touched the cavity in a decaying tooth

Examine at the end of three or four days. Notice the colonies of bacteria. Where did these bacteria come from? Why do bacteria grow so well in the cavity of a decayed tooth? Why do teeth decay? How many decayed teeth have you in your mouth? How can you save them? How often do you brush your teeth? Explain why this helps to prevent decay. What causes an ulcerated tooth? Why are people with decaying teeth more liable to catch dangerous diseases?

Problem 7 — Bacteria in drinking water

Class Problem. — Pour about three inches of water into a coffee can, and set a tube of agar into it. Heat until the



This garden was planted with four drops of good drinking water **This garden was planted with four drops of contaminated water**

The two samples of water looked just alike

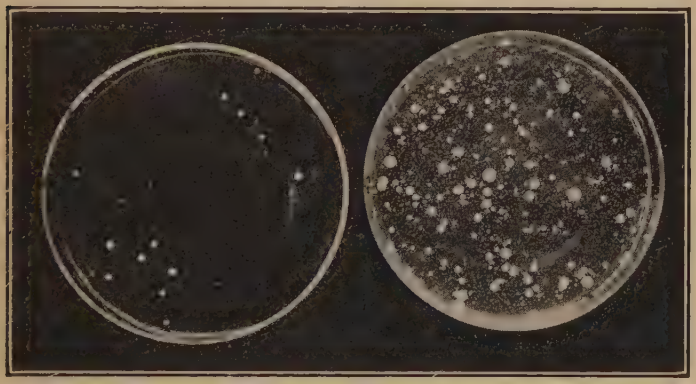
solid agar changes to a liquid. Cool for one or two minutes. Remove the cotton wad. With a short piece of sterilized tubing, put four drops of drinking water into the melted agar. Put this agar into a sterilized Petri dish, and let it harden. Label. Set the dish away in a warm, dark place.

Examine at the end of three or four days. Notice the colonies of bacteria. How many kinds do you apparently

find? Where did these bacteria come from? Where does your drinking water come from? What measures are taken to safeguard its purity?

Problem 8 — Bacteria in milk

Class Problem. — Using a short piece of sterilized glass tubing, put one drop of *pasteurized* milk into a tube of melted agar. Pour into a sterilized Petri dish. Label, *No. 1, Pasteurized milk.* Put one drop of milk that has



This garden was planted with one drop of pasteurized milk

This garden was planted with one drop of raw milk

not been pasteurized into a second tube of melted agar. Pour this into a second Petri dish that has been sterilized. Label, *No. 2, Milk not pasteurized.* Set the dishes away in a warm, dark place.

Examine at the end of three or four days. Which garden contains the greater number of bacteria colonies? How do you account for this? Why is pasteurized milk safest to use? How is milk pasteurized? What diseases are spread by dirty milk? What causes the souring of milk? Why does milk keep longer on ice? Where does the milk you use at home come from? *Is this milk safe?*

PROJECT VI

HOW TO KILL BACTERIA

Problems — 1. How heat kills bacteria.
2. How sunlight kills bacteria.
3. How bacteria are killed by disinfectants.

Problem 1 — How heat kills bacteria

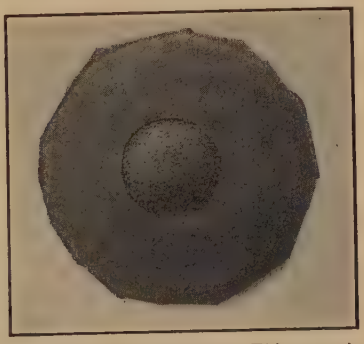
Home Problem. — Review Problem 1, page 351. How did you sterilize the nutrient agar in Problem 1, page 354? Why do you boil this agar? Examine the surface of the agar in one of the test tubes. Do you find any bacteria colonies? Explain. Why do surgeons boil their instruments after using them? Why do you boil dirty handkerchiefs? Some people boil water before they drink it. What is the purpose of this? Explain why canned goods, such as salmon, crab meat, soups, peas, beans, corn, etc., keep so well. Why do these foods spoil soon after you open the cans? How does your mother "can" vegetables at home? Do they ever spoil?

Problem 2 — How sunlight kills bacteria

Class Problem. — Take a new lead pencil with a rubber tip. Push the point of a needle into the tip so that the needle is held firmly in place. Remove the glass cover from a Petri dish containing colonies of bacteria. Transfer some of these bacteria from the Petri dish to the melted agar in a test tube, as follows: First touch one of the colonies gently with the needle, then dip the needle into the melted agar in the test tube. Repeat several times touching different colonies with the needle. Pour the melted agar from the test tube into a Petri dish and let

it harden. Cut a circular hole, one inch in diameter, in the center of a piece of black paper. If you have no black paper, soak a sheet of white paper in black ink, and let it dry. Lay the black paper over the top of the Petri dish, so that the circular hole comes in the center of the glass cover. Wrap the black paper around the dish, closely and neatly, and fasten the edges with glue. Set the Petri dish on a window sill in a warm room, where direct sunlight will strike it during the day.

At the end of three or four days remove the black paper. Hold the Petri dish up to the light and look through it. Notice the numerous tiny colonies of bacteria around the edge of the dish. Notice the clear, transparent spot in the center. Why is this spot clear? Do you find any bacteria colonies in this spot? Why did colonies of bacteria grow around the edge of the Petri dish? What killed the bacteria in the center? What effect does direct sunlight have on bacteria? Why are sunny rooms more healthful than dark rooms? Does your mother keep the window shades pulled down at home? Is this a good plan?



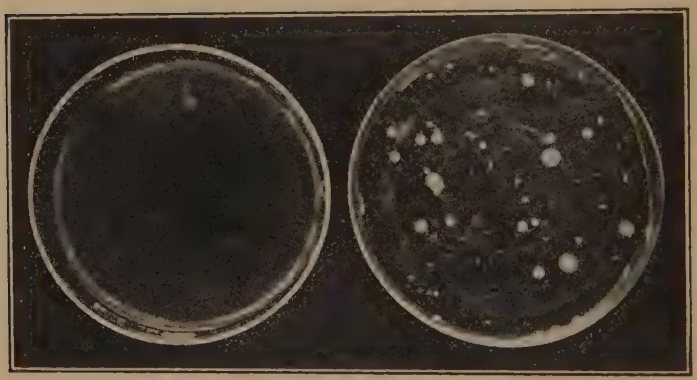
Sunlight kills bacteria. This experiment proves it

In some thickly settled tenement districts, all direct sunlight is shut off by the crowded buildings. Do you consider these tenements healthful to live in? Why do many hospitals have sun parlors for their patients? Why are diseases, such as colds and pneumonia, more common in winter than during the summer? Do you live

in bright sunny rooms? Do you play out of doors every day?

Problem 3 — How bacteria are killed by disinfectants

Class Problem. — Half fill two test tubes with melted agar. Remove the glass cover from one of the Petri dishes containing colonies of bacteria. Touch several colonies with a needle and then dip the needle into the melted agar in each test tube. Repeat several times. Pour the melted agar from one test tube into a Petri dish. Label this dish, *No. 1, Without iodine.* Into the second test tube, put a teaspoonful of strong iodine solution. Pour the contents



Both gardens were planted with bacteria. Iodine was added to one but not to the other

of this test tube into a second Petri dish. Label this dish *No. 2, With iodine.* Set the two Petri dishes away in a warm, dark place.

Examine at the end of three or four days. Notice the colonies of bacteria in dish No. 1. Do you find any bacteria colonies in dish No. 2? How do you account for this? Why do you put iodine on cuts and

wounds? Explain why the wound heals more quickly if so treated.

In addition to iodine solution, try the effects of other disinfectants, as follows:

1. A teaspoonful of dioxogen.
2. A teaspoonful of sylpho-nathol solution.
3. A teaspoonful of mercury bichloride solution.
4. A teaspoonful of carbolic acid solution.
5. A teaspoonful of chloramine T solution.

What kinds of disinfectants do you use at home? How do you use these disinfectants? For what purposes? How do you treat a cut or a wound? What causes blood poisoning? How can you prevent it? Some people gargle their throats with disinfectants when they have a cold. Why do they do this?

FACTS EVERY ONE SHOULD KNOW ABOUT MICROSCOPIC ORGANISMS

Microscopic Organisms. — For many centuries the world of little things remained undiscovered. People knew nothing about the countless millions of invisible plants and animals that live in water, soil, air, foods, and in our own bodies. Milk soured, fruit juices fermented, meats putrified, vegetables decayed, and terrible diseases claimed many unfortunate victims, but people were totally ignorant of the real causes. They did not know that these conditions were brought about by millions of extremely tiny plants and animals, far too small to be seen by the naked eye. In 1683, a Dutch linen weaver constructed a lens sufficiently powerful to enable him to see some of these tiny objects. The importance of this remarkable discovery was not realized at that time. Nearly two centuries more passed away before scientists began to study the world of little things in earnest.

The microscopic organisms that concern us most in our daily lives are certain plants which are commonly called yeast, molds, and bacteria. These differ in many respects from the plants that grow in your garden. They have no green leaves, stems, or roots. They do not produce flowers or seeds. They cannot manufacture starch or sugar. They are dependent plants. Some of them live on dead animal or vegetable matter. Others attack living plants and animals. Their chief function seems to be destructive rather than constructive. They destroy rather than build up.

Fermentation. — When sweet cider is allowed to stand, it ferments. At first you will notice many tiny bubbles rising in the liquid. These are bubbles of a gas called carbon dioxide. The sugar soon disappears. The juice is

no longer sweet. The liquid has a peculiar, sharp, pungent taste, due to the presence of alcohol. All these changes are brought about by invisible yeast plants that float about in the air. Some of them fell into the apple juice and multiplied very rapidly. The yeast plants used the sugar for food and gave off as waste products carbon dioxide and alcohol. The same thing happens when a jar of your mother's preserves spoils. Perhaps she did not kill all the yeast plants when she boiled the fruit, or the cover of the jar may have been loose. The preserves develop a peculiar, pungent taste. Sometimes the jar explodes, due to the formation of much carbon dioxide.

Yeast. — A fresh yeast cake looks dead, but it isn't. It is composed of countless yeast plants, mixed with potato starch or some other substance. If you examine some of the cake under a microscope, you will see many oval cells that look like tiny eggs. It is most interesting to watch these plants multiply. Tiny oval buds grow right out from the side of the mother cell. Some of these increase in size, break off, and again produce tiny buds. Under favorable conditions, with warmth, moisture, and plenty of sweet food, the number of yeast plants increases at a surprising rate. Some yeasts when given plenty of moisture, but insufficient food, form *spores*. These spores may live a long time. They can endure severe cold, drying, and considerable heat. They are carried about by particles of dust in the air. Whenever they fall into warm, sweet liquids they soon grow into yeast plants, and start fermentation.

When your mother makes bread, she mixes yeast and sugar with the dough. Then she usually sets the pan of dough away in a warm place, until the following morning. During the night the yeast plants multiply by budding.

They use the sugar as food, changing it into carbon dioxide and alcohol. The carbon dioxide is held by the sticky dough in many little bubbles, and makes the dough rise. When the bread is baked, alcohol is driven off. Each bubble of gas expands, on account of the heat, and the bread rises still more. Sometimes the dough fails to rise. Perhaps it is too cold, or the tiny yeast plants may be dead.

Molds. — Molds are very common plants, especially in damp cellars. They cause the decay of fruits, vegetables, and meats. They even attack wood, paper, cloth, and leather. Black mold causes bread to spoil. This consists of many fine white threads, which bear thousands of tiny black balls. Each ball is filled with microscopic spores, which escape, and float about in the air. Wherever they find suitable conditions, these spores sprout and produce new mold plants. The best conditions for growth are warmth, moisture, and darkness.

Green mold is common on fruits, especially lemons and oranges. Blights and mildews are forms of mold. These attack living plants and destroy millions of dollars' worth of crops yearly. Frequently we find molds in decaying leaves, wood, grasses, and manure. Here they are performing a great service to man, for they are helping to break up these dead materials into rich soils and soluble plant foods. In this way molds help to feed the world.

Perhaps you have wondered how molds can live on solid foods; how they can break up and destroy wood, leather, dead leaves, and straw. They have no teeth or even mouths. All of their food must be changed to a liquid before they can absorb it. This change is brought about by certain fluids, called *enzymes*, which molds produce and give out. These enzymes spread out into the materials in which the molds are growing, and digest them, in some-

what the same manner that foods are digested in your own stomach and intestines.

Mold spores are hard to kill. They can endure intense cold, long drying, and even the temperature of boiling water. They live for months clinging to particles of dust. They are always present in your home, in every room. You inhale them when you breathe. Your mother is kept busy trying to protect her food from the spores of molds. She puts her meats, fish, sauces, and cooked vegetables in the refrigerator. She keeps her bread and cake in clean tins or covered jars. She covers her jellies with paraffin. She protects her cereals and flour from moisture. When she " cans " fruits or vegetables she boils them for a long time before she seals the jars.

Bacteria. — Bacteria are the tiniest of all living things, and the most numerous. Scrape a little tartar from your teeth with a toothpick. This mass of sticky tartar is alive with thousands of active, growing bacteria; but you can't see them. Examine some of the tartar under a powerful microscope, and many tiny objects will become visible. Some are shaped like a marble, some like a sausage, and others may be more or less curved. Some are quiet, others spin round and round or dart rapidly back and forth. These tiny objects are bacteria, the simplest of all plants. They consist of minute masses of jelly-like *protoplasm*, covered with a thin membrane. They absorb liquid foods through this membrane and throw off waste products in the same manner.

Tie a string around the middle of a sausage, and draw it tight. Don't break the skin. You can make two small sausages out of a single larger one. This will give you some idea as to the manner in which bacteria multiply. A thin partition or cross wall splits the full-grown mother cell into

two smaller cells. These are "baby" bacteria. They usually separate, grow to full size, and again split in two. Under very favorable conditions, a single "baby" bacterium may develop into a full-grown mother cell and produce offspring within twenty minutes. This almost incredible increase in numbers is of great importance, for herein lies the secret of the tremendous power of bacteria to do good or cause destruction. A few millions are of little consequence. They are too small. You could pile them all on the head of a pin. But suppose you swallow a single typhoid fever germ at breakfast time, and multiplication takes place only once an hour. The following morning at breakfast time, an army of over sixteen million typhoid germs may be swimming around in the fluids of your stomach, intestines, and blood. Beyond this the increase soon reaches numbers too large for the imagination to grasp. Countless myriads swarm through the body fluids, giving off poisons that cause headaches, fever, and delirium. Your body wastes away and you become weaker and weaker. Death may follow unless this increase is checked and the typhoid germs destroyed. You can't tell when you "catch" a disease. It may take several days or longer before you begin to feel any effects. During this interval the germs multiply rapidly in your body, until sufficient numbers are produced to make you ill.

Some people believe that all bacteria are harmful. This is not true. By far the greater majority are our allies. They work with molds to keep the world clean and a fit place in which to live. They clean up piles of refuse. They change filthy sewage and human waste into harmless, odorless substances. They transform the dead leaves and dead grass of the previous year into rich black *humus*. Bury a pailful of garbage in your garden and it soon disappears.

Plant a few seeds, such as corn, peas, or beans, in the same spot and the plants will grow bigger and yield a larger crop. Similar results are obtained when you spread manure on your garden. When the Indians planted corn they used to put a dead fish in each hill. The fish decayed and made the corn grow better. All these changes are brought about by molds and soil bacteria. The roots of plants, as you know, cannot take in solid foods. They have no teeth or even mouths. These foods must first be broken up and changed into simpler substances, which dissolve in soil water. Roots absorb these liquid foods and plants use them to manufacture the grains, fruits, and vegetables that you and I eat. Without the aid of bacteria farmers would soon be unable to raise sufficient crops to feed the world.

At home, your mother must guard incessantly against the attacks of yeasts, molds, and bacteria. Of these foes, however, bacteria are the most numerous and the most difficult to combat. Cold checks the growth of bacteria. Therefore your mother puts some foods on ice. Preservatives also check their growth. Pickles are kept in vinegar, eggs in water glass, and salt in brine.

When foods are "canned," they are boiled to kill bacteria and other plants. Some species of bacteria produce spores. A tiny rounded mass covered with a hard tough shell is formed inside the cell. This may escape and later, under proper conditions, sprout into a new bacterium. The spores of bacteria are even harder to kill than mold spores.

Of all the microscopic plants and animals about us, the most harmful are those that cause disease. Life is a continual fight against these invisible foes. They are responsible for much of the suffering in the world, and over half the deaths.

It was not until about fifty years ago, however, that the relation of these organisms to disease was discovered. In 1876, Robert Koch proved that anthrax, a fatal disease of domestic animals, a disease that caused a yearly loss of millions of dollars to the farmers of Europe, was caused by a rod-shaped bacterium. A few years later Louis Pasteur discovered a new and wonderful cure for anthrax. He prepared a vaccine, by growing the bacteria at extreme temperatures. Under these conditions they lost their power to produce death; and when Pasteur injected some of these weakened organisms into the bodies of sheep and cattle, the animals became *immune*, or safe from the attacks of anthrax.

Relation of Bacteria to Disease. — Have you ever been vaccinated for smallpox? *You ought to be.* This terrible disease killed millions of people in Europe during the eighteenth century. To-day, in countries where vaccination is compulsory, smallpox has practically disappeared. If you are vaccinated once in infancy and again when you grow up, you will be immune from smallpox.

Diphtheria is a very serious disease. It is caused by a rod-shaped bacillus, with a peculiar beaded appearance. This usually lodges in the throat and grows there, forming white patches. A deadly poison or *toxin* is given off. This toxin is carried by the blood all over the body, and frequently affects the heart, lungs, and kidneys with fatal results. As soon as the doctor discovers that you have diphtheria he injects a small quantity of a colorless liquid, called antitoxin, into your blood. This antitoxin is taken from the blood of horses which have undergone special treatment. If the doctor injects it promptly, when you are first sick, your chances of recovery are very much increased.

Typhoid fever is an intestinal disease, caused by another rod-shaped bacillus. Tufts of tiny hairs, called cilia, are attached to this organism, so that it swims about very rapidly in liquids. The typhoid bacillus is usually taken into your system with food and drink. All soldiers and many private citizens are now protected from typhoid by a liquid containing dead typhoid germs, which is injected into the blood. This method has proved very effective in lessening the dangers of this much-dreaded disease.

Tuberculosis, commonly called the *Great White Plague*, has caused more deaths than any other disease. Thousands of deaths occur in the United States every year. Tuberculosis is caused by a tiny rod-shaped bacillus that attacks many parts of the human body, such as the skin, glands, bones, and lungs. When it attacks the lungs, we call the disease consumption. Consumption is undoubtedly one of the worst diseases that attacks human beings. Sometimes it lingers for years. It is characterized by spasms of coughing and the raising of " phlegm " that contains millions of active bacilli. The lungs are gradually destroyed and the body wastes away. Many consumptives are found among people who work or live indoors, especially where there is dust, poor ventilation, dark rooms, and unclean conditions. Consumption can be cured in its early stages. The cure consists of plenty of fresh air, sunshine, nourishing foods, and complete rest.

Common colds are " catching " diseases caused by several kinds of bacteria. Colds are more serious than some people realize, for they weaken the body and lessen its resistance to " fight off " other diseases, such as tuberculosis, influenza, and pneumonia.

Scarlet fever, whooping cough, chicken pox, and measles are common diseases, especially of young people. These

diseases are very contagious, or "catching." Scientists have never discovered the organisms that caused them. Probably these organisms are too small to be visible, even under the most powerful microscope.

The best way to study bacteria is to raise them in glass gardens, called Petri dishes. If you plant these gardens with bacteria and set them away for several days in a warm, dark place, each bacterium will start to grow and multiply into a colony containing millions and millions of organisms. You can see the colonies very plainly with the naked eye. Some may be red. Others are yellow, green, white, or opalescent. Some are raised, others spread out in a thin sheet. Some have regular margins; the margins of others are wavy or indented. These peculiarities show that each individual colony is composed of a certain kind of bacteria. The glass gardens that you planted showed you many interesting facts about bacteria. Most important of all, you discovered how "catching diseases" may travel. The germs may be carried by dust particles in air. They may be carried by dirty hands. They may be thrown out of your mouth when you cough or sneeze. They may come from the cavity of a decaying tooth. House flies may carry them. They may be present in drinking water or milk.

In addition to these, there are other ways for diseases to travel. Malaria and yellow fever are transmitted by certain kinds of mosquitoes, typhus fever by lice, the bubonic plague by fleas, and hydrophobia by "mad" dogs or cats.

We hope the bacteria gardens taught you some valuable lessons. Don't stir up dust. Wash your hands before eating. Always cough or sneeze into a handkerchief. Brush your teeth morning and night. Have all cavities filled by a dentist. Keep flies away from foods. Swat flies whenever

you can. Drink pure water from safe sources. Buy "certified" or pasteurized milk if you live in the city. If you live in the country buy milk from clean dairies.

You planted one glass garden with bacteria, and covered it with black paper having a circular hole in the center. Then you left this garden in a sunny window for several days. When the black paper was removed, you noticed a clear round spot in the agar, directly under the hole. No colonies grew in this spot. Surrounding the clear spot, you found many colonies of bacteria. Direct rays of sunlight kill disease germs. Do you live in bright sunny rooms? Do you keep the window shades pulled down during the day? Remember that sunshine helps you to keep well.

You planted another glass garden with bacteria and added iodine solution. No colonies of bacteria appeared in this garden. The agar remained clear. Iodine solution killed all the bacteria present. Keep disinfectants, such as iodine, at home for emergencies. Treat all cuts and wounds with them. Disinfectants kill the germs that may cause lockjaw or blood poisoning.

In spite of every precaution, you will not be able to avoid all the invisible foes about you. Disease germs are far too common for you to escape them all. Some of them will undoubtedly find their way into your body. Whether or not these germs cause disease depends in a large measure on your own physical condition. Keep your body in good physical condition. Practice right habits of living. Open your bedroom windows at night. Breathe deeply. Eat plain, wholesome foods. Don't stuff. Watch out for constipation. Empty the large intestine every day. Keep clean. Brush your teeth regularly. Drink plenty of good water. Play out of doors all you can. Go to bed early.

Get at least eight hours sleep every night. These right habits of living are your best safeguards against the attacks of the invisible foes about you. *Keep your body in fighting trim.*

INDIVIDUAL PROJECTS

You will find below a list of *Individual Projects.* These are scientific investigations for you to carry on by yourself. We want you to apply the facts you have learned, to see if you can make some improvements, either for your own welfare or that of your home. *Choose the project most interesting to you.* Try simple experiments if necessary. Consult books. Cut pictures and clippings from papers or magazines. Ask questions of your parents. *They will help you.* Keep a neat record of all your work either in a notebook or on loose sheets of paper. When finished, you can tie these loose sheets together and make a very attractive little booklet. *Each project is a test of your own ability. See how many you can do during the school year.*

1. Make a kite and fly it.
2. Take an air rifle apart and study it.
3. Make a toy airplane that will fly.
4. Make a toy sailboat and sail it.
5. Change an automobile tire and patch the inner tube.
6. Take an air pump apart and study it.
7. Know how a vacuum cleaner works.
8. Determine the best method to "air out" your bedroom.
9. Know how to can fruits or vegetables.
10. Know how to "put up" eggs in water glass.
11. Prepare a meal in a fireless cooker.
12. Make a collection of good recipes for cooking.
13. Cook and serve a dinner at home, at a cost of not over thirty-five cents per plate.
14. Know at least ten good chafing dish recipes.
15. Plan an appetizing, well-balanced picnic lunch for four persons.
16. Know how to cook a meal in camp, over an open fire.
17. Make a siphon and use it.
18. Make a water wheel that will run.

19. Take a lift pump apart and study it.
20. Examine a real force pump and find out how it works.
21. Know how to run a toy steam engine.
22. Make a freezerful of ice cream or sherbet.
23. Know how to clean out a trap in a waste pipe.
24. Investigate the source and safety of your home water supply.
25. Know how to shut off the water and repair a leaking faucet.
26. Know how to empty and fill a hot water tank.
27. Read your water meter and determine the cost of water per month.
28. Make a toy wind mill and set it up.
29. Make a wind vane that tells wind direction.
30. Know how to read a barometer.
31. Observe changes in the weather for one month.
32. Know how to kindle a fire by some primitive method.
33. Kindle a fire at least ten times in your kitchen range or fireplace.
34. Know how to check a fire for the night in your heater.
35. Know how to use a fire extinguisher.
36. Make your own home safe from fire.
37. Know how to turn in a fire alarm.
38. Study the parts and operation of your coal range.
39. Take full charge of the care and operation of your heating system for one month.
40. Make a fireless cooker that works.
41. Know how to use a kerosene or gasoline stove.
42. Clean and adjust the burners on your gas range.
43. Know how to use a camera. Develop and print the pictures yourself.
44. Clean and care for the kerosene lamps at home for one month.
45. Know how to adjust a Welsbach gas lamp, and put on a new mantle.
46. Throw away poor gas lamps and install good ones.
47. Know how to read your gas meter and check a gas bill.
48. Know how to save gas when you use the gas range.
49. Examine an electric bulb and study its parts.
50. Draw a plan to show how your house is wired for electricity.
51. Know how to put in a new fuse when an old one "blows out."
52. Know how to read an electric meter and check your monthly bill.

53. Make a compass that will tell direction.
54. Make an electro-magnet and use it.
55. Take an old dry cell apart and study it.
56. Recharge your sal-ammoniac cells at home.
57. Take a pocket flashlight apart and find out how it works.
58. Know how to receive messages by wireless.
59. Know how to send wireless messages.
60. Find out how a spark coil works.
61. Know how to run a toy motor or dynamo.
62. Install an electric bell system at home.
63. Examine an electric bell and find out how it works.
64. Make a telegraph key and sounder and operate them.
65. Copper plate some article at home.
66. Know how to keep a storage battery in working order.
67. Make a cake of soap at home.
68. Weave three pieces of cloth of different kinds of fibers.
69. Know how to care for and operate a washing machine.
70. Make a collection of fifty samples of cloth.
71. Know how to dye clothing materials at home.
72. Know how to make bread and bake it.
73. Clean and care for the refrigerator at home for one month.
74. Determine the best methods to get rid of flies.
75. Know how to pasteurize milk at home.
76. Determine the best methods for sweeping and dusting.
77. Know how to keep your teeth in good condition. Consult a dentist if necessary.
78. Know how to disinfect and dress a cut or wound.
79. Make your home a more healthful place to live in.
80. Draw up a list of at least ten good rules on how to keep well.

GENERAL SCIENCE LIBRARY

Start a General Science Library. The following publications have been carefully selected and tested. They are practical, non-technical, and written in a style that appeals peculiarly to the tastes of young people.

Interesting Magazines for Boys and Girls

National Geographic, Hubbard Memorial Building, Washington, D. C.
Good Housekeeping, 119 West Fortieth Street, New York.
Popular Science Monthly, 229 Fourth Avenue, New York.
The Scientific Monthly, Science Press, Garrison, N. Y.
Illustrated World, Drexel Ave., and Fifty-Eighth St., Chicago.
Philosophy of Health, J. H. Tilden, M.D., Denver, Colorado.
Nature Study Review, Comstock Publishing Co., Ithaca, N. Y.
Popular Mechanics, 6 North Michigan Avenue, Chicago.
Bird Lore, D. Appleton & Company, New York.
Wireless Age, Marconi Publishing Corporation, 450 Fourth Avenue, New York.
Electrical Experimenter, Experimenter Publishing Co., 233 Fulton St., New York.
Kodakery, Eastman Kodak Company, Rochester, N. Y.

Interesting Books for Boys and Girls

Boy Scouts of America, Official Handbook, Doubleday, Page & Co.
The Book of Knowledge, The Grolier Society, New York.
The Book of Wonders, Presbrey Syndicate, New York.
Child's Book of Knowledge, F. H. Hinckley & Co., Boston.
Fairyland of Science (Buckley), D. Appleton & Company.
Wonders of Science, E. M. Tappan, Editor, Houghton Mifflin Co.
Great Inventors and Their Inventions (F. P. Bachman), American Book Co.
Story of Great Inventions (E. E. Burns), Harper & Bros.
The Story Book of Science (J. H. Fabre), Century Company.
Miracles of Science (Williams), Harper & Bros.
Science Byways (Proctor), J. B. Lippincott Co.
Borderland of Science (Proctor), J. B. Lippincott Co.
Wonders of Science (Lackland), Chas. Scribner's Sons.
The Threshold of Science (Wright), J. B. Lippincott Co.
Experimental Science (Hopkins), Munn & Co., New York.
Let Me Explain (Williams), Caldwell & Co., New York.
Something To Do Boys (E. A. Foster), W. A. Wilde Co.

The Outdoor Handy Book (D. C. Beard), Chas. Scribner's Sons.
The Field and Forest Handy Book (D. C. Beard), Chas. Scribner's Sons.
The Thermometer and its Family Tree (P. R. Jameson), Taylor Instrument Co., Rochester, N. Y.
Weather Series for the Amateur (P. R. Jameson), Taylor Instrument Co., Rochester, N. Y.
Boy's Book of Inventions (R. S. Baker), Doubleday & McClure.
The Wonder Book of the Atmosphere (E. J. Houston), Fred A. Stokes Co.
Fresh Air and How to Use It, National Association for Study of Tuberculosis, 105 East Twenty-Second Street, New York.
Food, What it is and does (Edith Grier), Ginn & Co.
Feeding the Family (Mary S. Rose), The Macmillan Co.
Food and Household Management (Kinne and Cooley), The Macmillan Co.
Earth and Sky Every Child Should Know (J. E. Rogers), Doubleday, Page & Co.
Giant Sun and His Family (M. Proctor), Silver Burdett & Co.
The Book of Stars (A. F. Collins), D. Appleton & Co.
The Friendly Stars (M. E. Marten), Harper & Bros.
Electricity and Its Every-day Uses (J. F. Woodhull), Doubleday, Page & Co.
Harper's Everyday Electricity (D. C. Shafer), Harper & Bros.
The Book of Electricity (A. F. Collins), D. Appleton & Co.
The Book of Wireless (A. F. Collins), D. Appleton & Co.
The Boy Electrician (Morgan), Allyn & Bacon.
Shelter and Clothing (Kinne and Cooley), The Macmillan Co.
How the World Is Clothed (F. G. Carpenter), American Book Co.
From Wool to Cloth (American Woolen Co.), Boston.
The Study of Fabrics (Turner), D. Appleton & Co.
The House Fly (Howard), Fred A. Stokes Co.
Life History of American Insects (Weed), The Macmillan Co.
Farm Friends and Farm Foes (Weed), D. C. Heath & Co.
Our Insect Friends and Enemies (Smith), J. B. Lippincott Co.
A Year in a Coal Mine (Husband), Houghton Mifflin Co.
Avoidance of Fires (Weeks), D. C. Heath & Co.
Forms of Water (Tyndall), D. Appleton & Co.
The Story of Oil (W. S. Tower), D. Appleton & Co.
Diggers in the Earth (E. M. Tappan), Houghton Mifflin Co.
Extinct Monsters (Hutchinson), D. Appleton & Co.
Sketches of Creation (Winchell), Harper & Bros.
Trees Every Child Should Know (J. E. Rogers), Doubleday, Page & Co.
Birds of Village and Field (F. I. Merriam), Houghton Mifflin Co.
Bacteria, Yeasts and Molds (Conn), D. Appleton & Co.
The Story of Germ Life (Conn), D. Appleton & Co.
The Kingdom of Dust (Ogden), Popular Mechanics Co., Chicago.
Preventable Diseases (Woods Hutchinson), Houghton Mifflin Co.

Primer of Sanitation (Ritchie), World Book Co.
Good Health (Jewett), Ginn & Company.
Handbook of Health (Woods Hutchinson), Houghton Mifflin Co.
Healthy Living (Winslow), Chas. E. Merrill Co.
How to Live (Fisher and Fisk), Funk & Wagnalls.
Fuels of the Household (Marian White), Whitcomb & Barrows, Boston.

The following Farmers' Bulletins are especially valuable and practical. Published by United States Department of Agriculture, Washington, D. C.

No. 34 Meats; Composition and Cooking
No. 44 Commercial Fertilizers
No. 54 Some Common Birds
No. 85 Fish as Food
No. 121 Beans, Peas, and Other Legumes as Food
No. 127 Important Insecticides
No. 131 Household Tests of Butter
No. 154 The Home Fruit Garden
No. 157 The Propagation of Plants
No. 181 Pruning
No. 196 Usefulness of the American Toad
No. 203 Canned Fruits, Preserves, and Jellies
No. 243 Fungicides
No. 255 The Home Vegetable Garden
No. 270 Modern Conveniences for the Farm Home
No. 345 Some Common Disinfectants
No. 348 Bacteria in Milk
No. 359 Canning Vegetables in the Home
No. 363 The Use of Milk as Food
No. 375 Care of Food in the Home
No. 377 Harmfulness of Headache Mixtures
No. 389 Bread and Bread Making
No. 428 Testing Farm Seeds in the Home
No. 459 House Flies
No. 478 How to Prevent Typhoid Fever
No. 839 Canning by the Cold-Pack Method
No. 841 Drying Fruits and Vegetables in the Home.

Safety for the Household, Circular 75, U. S. Bureau of Standards. Measurements for the Household, Circular 55, U. S. Bureau of Standards.

EQUIPMENT

The equipment needed to teach this text has been standardized with great care. Costly pieces of apparatus are avoided. A complete new equipment can be purchased for less than two hundred dollars. A considerable part of the equipment can be used for many years. Wherever possible, home-made apparatus is recommended.

The following equipment can be purchased from any of the following firms:

Central Scientific Co., Chicago, Ill.
Standard Scientific Co., New York, N. Y.
W. M. Welch Scientific Co., Chicago, Ill.
Braun-Knecht-Heimann Co., San Francisco, Cal.
L. E. Knott Apparatus Co., Cambridge, Mass.
Cambridge Botanical Supply Co., Waverly, Mass.

The authors have selected from the stock of L. E. Knott Apparatus Co., the designs particularly adapted to this book.

The authors recommend that such items as come under headings, Hardware and Kitchen Utensils, Miscellaneous Supplies, be purchased locally. The various apparatus houses will usually, as an accommodation to the busy teacher, purchase these items in the open market, for which service in order to pay for the cost of handling, they find it necessary to bill at a slight advance over the market price.

Prices

Prices noted were current during the preparation of the manuscript for this book. The authors have reason to believe that the prices will be lower, especially should an order be placed for the complete equipment. It is a good plan to submit your list to several firms for competitive bids.

Chemicals and Reagents

All chemicals, unless otherwise specified, are commercial grade. Quantities suggested are carefully estimated and will be found sufficient for all experiments.

6 lb. Bottle Hydrochloric Acid	lot	$1.25	$1.25
7 lb. Bottle Nitric Acid	lot	1.90	1.90
9 lb. Bottle Sulphuric Acid	lot	1.50	1.50
2 lb. Ammonium Chloride (Sal-ammoniac) . .	lb.	.35	.70
1 oz. Peptone	oz.	.60	.60

4 oz. Agar-Agar		lot	$.75	$.75
12 oz. Bleaching Powder (Calcium Hypochlorite)		lot	.25	.25
1 lb. Carbon Bisulphide		lb.	.50	.50
8 oz. Carbon Tetrachloride		lot	.35	.35
1 lb. Charcoal, wood, lumps		lb.	.12	.12
2 lbs. Copper Sulphate, crystals (Blue Vitriol)		lb.	.20	.40
1 lb. Ether, U. S. P.		lb.	.75	.75
1 gal. Alcohol, denatured		gal.	1.75	1.75
1 pkg. Fehling's Solution tablets		pkg.	1.00	1.00

N. B. — Full directions for making both Copper and Alkaline Solutions accompany each package.

1 oz. Iodine, resublimed, U. S. P.	oz.	.75	.75
2 oz. Lycopodium Powder	lot	.75	.75
8 oz. Manganese Dioxide, powdered, 95%	lot	.25	.25
5 lb. Marble Chips (Calcium Carbonate)	lot	.40	.40
4 oz. Magnesium Powder	lot	1.25	1.25
2 lb. Mercury, redistilled	lb.	1.50	3.00
8 oz. Malt, ground (raw)		.70	.70
2 Sheets Litmus Paper, red	sheet	.10	.20
2 Sheets Litmus Paper, blue	sheet	.10	.20
1 oz. Oxalic Acid, crystallized	oz.	.15	.15
4 oz. Phosphorus, Yellow, sticks	lot	.60	.60
1 lb. Potassium Chlorate, crystallized	lb.	.75	.75
4 oz. Potassium Iodide, crystallized, U. S. P.	lot	1.50	1.50
8 oz. Potassium Hydroxide, sticks	lot	.60	.60
1 lb. Sulphur Flowers	lb.	.15	.15
1 lb. Zinc, granulated (Mossy)	lb.	.35	.35
			$23.42

Chemical Apparatus

Quantities suggested are ample to replace ordinary breakage. Catalogue Numbers refer to catalogues of L. E. Knott Apparatus Co., Cambridge, Mass.

2 Pyrex Glass Beakers, Griffin lip, 400 cc.	3628*e*	ea.	$.33	$.66
4 Pyrex Glass Beakers, Griffin lip, 600 cc.	3628*f*	ea.	.39	1.56
2 Pyrex Glass Erlenmeyer Flasks, 300 cc.	5421*f*	ea.	.28	.56
8 Pyrex Glass Erlenmeyer Flasks, 500 cc.	5421*g*	ea.	.32	2.56
2 Pyrex Glass Erlenmeyer Flasks, 1000 cc.	5421*j*	ea.	.46	.92
1 Bunsen's Glass Funnel, 3 inch	5450*c*	ea.	.36	.36
1 Bunsen's Glass Funnel, 4 inch	5450*d*	ea.	.45	.45
1 Bunsen's Glass Funnel, 6 inch	5450*f*	ea.	.78	.78
4 Wide Mouth Glass Bottles, ½ pint (8 oz)	3738*d*	ea.	.30	1.20

2 Wide Mouth Glass Bottles, 1 pint (16 oz.)	3738*e*	ea.	$.40	$.80
12 Glass Vials, straight wall, with corks . .	7080*a*	lot	.14	.14
1 Cylindrical Jar (12×2)	31–250*b*	ea.	1.25	1.25
2 Steel Forceps	5445	ea.	.17	.34
6 pcs. Iron Gauze with Asbestos center . .	5632	ea.	.16	.96
1 Box Gummed Labels (1×$\frac{7}{8}$″), No. 217. .	5750	box	.10	.10
1 pkg. Filter Paper, 4 inch	5365*b*	pkg.	.21	.21
1 Wood Test Tube Rack for 13 tubes, with drying pins	6715	ea.	.85	.85
20 ft. Antimony Rubber Tubing $\frac{3}{16}$″ . . .	6500	ft.	.09	1.80
15 ft. Antimony Rubber Tubing $\frac{1}{4}$″ . . .	6500	ft.	.12	1.80
6 ft. Antimony Rubber Tubing $\frac{3}{8}$″ . . .	6500	ft.	.21	1.26
2 Test Tube Clamps	4040	ea.	.10	.20
2 Battery Jars, 4×5 inch	31–265*b*	ea.	.40	.80
2 Battery Jars, 6×8 inch	31–265*c*	ea.	.60	1.20
4 Thistle Tubes, 10 inch	6955*a*	ea.	.12	.48
1 Gross Test Tube, 6×1 inch	6795*g*	gr.	4.75	4.75
3 lb. Glass Tubing $\frac{1}{4}$″	6970	lb.	.60	1.80
2 lb. Glass Tubing $\frac{3}{8}$″	6970	lb.	.60	1.20
8 oz. Glass Capillary Tubing, 1 mm. bore .	6973	lb.	1.15	.58
1 Porcelain Mortar and Pestle, 4$\frac{1}{2}$″ . . .	6224*b*	ea.	1.20	1.20
18 Glass Petri Dishes, 4″	5159	ea.	.32	5.76
3 Triangular files, 5″	5351	ea.	.16	.48
6 ea. Cork Stoppers $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, 1$\frac{1}{8}$, 1$\frac{1}{4}$, and 1$\frac{3}{8}$ inches diameter.	4095	lot	.50	.50
3 ea. Cork Stoppers 1$\frac{1}{2}$, 1$\frac{5}{8}$, 1$\frac{3}{4}$, and 2 inches diameter	4095	lot	.46	.46
4 Two-holed Antimony Rubber Stoppers to fit 500 cc. Erlenmeyer Flasks (K 28) . .	6515	ea.	.18	.72
4 One-holed Antimony Rubber Stoppers to fit 500 cc. Erlenmeyer Flasks (K 28) . .	6515	ea.	.18	.72
2 Solid Antimony Rubber Stoppers to fit 500 cc. Erlenmeyer Flasks (K 28) . . .	6515	ea.	.18	.36
4 One-holed Antimony Rubber Stoppers to fit 6×1 inch Test Tubes (K 25) . . .	6515	ea.	.16	.64
2 Two-holed Antimony Rubber Stoppers to fit $\frac{1}{2}$ pint Wide-mouth Bottles (K 30) .	6515	ea.	.22	.44
2 One-holed Antimony Rubber Stoppers to fit $\frac{1}{2}$ pint Wide-mouth Bottles (K 30) .	6515	ea.	.22	.44
1 pkg. Wood Splints	6570	pkg.	.30	.30
1 Porcelain Evaporating Dish, 10 cm. diam.	5141*b*	ea.	.53	.53
1 Dozen Paraffin Candles (12 S)	70–50*b*	lot	.40	.40
				$42.52

Physical Apparatus

4 Bunsen Burners	60–20	ea.	$.45	$1.80
1 Rubber Bag, pure gum	43–230	ea.	1.65	1.65
1 Sensitive Hand Balance	15–200	ea.	3.85	3.85
2 Ring Stands, large	6691*c*	ea.	1.00	2.00
4 Open Side Rings, 4 inch	6461*c*	ea.	.37	1.48
2 Burette Clamps	4000	ea.	.40	.80
1 Bunsen's Clamp, round jaws	4006	ea.	.45	.45
1 Bunsen's Clamp, one flat and one V-shaped jaw	4008	ea.	.65	.65
2 Clamp Holders	4017	ea.	.28	.56
2 Screw Compressors	4032*a*	ea.	.28	.56
1 Set Brass Weights, 1 cg. to 100 grams	16–315	set	4.00	4.00
1 Laboratory Wall Thermometer, metal scale on hard wood back, –30 to 120° F.	63–12	ea.	1.75	1.75
2 Fahrenheit Chemical Thermometers, stem scale, white enamel back, 15–220° F.	63–56	ea.	1.50	3.00
1 Ground Glass Ungraduated Thermometer	63–20	ea.	1.40	1.40
1 Glass Model Lift Pump	35–30	ea.	2.25	2.25
1 Glass Model Force Pump	35–32	ea.	2.50	2.50
1 Hoffman's H-Form Electrolysis of Water Apparatus, large demonstration form-Special, with glass stop cocks		ea.	10.00	10.00
1 Barometer Tube	41–155	ea.	.65	.65
1 Gilley Improved Mercury Well	41–160	ea.	.55	.55
1 Copper Rod, 12×$\frac{1}{2}$″		ea.	.75	.75
1 Aluminum Rod, 12×$\frac{1}{2}$″		ea.	.40	.40
1 Brass Rod, 12×$\frac{1}{2}$″		ea.	.40	.40
1 Iron Rod, 12×$\frac{1}{2}$″		ea.	.28	.28
4 Straight Form Glass Lamp Chimneys	61–161	ea.	.35	1.40
1 One-holed Antimony Rubber Stopper to fit above chimneys (K 43)	6515	ea.	.60	.60
1 Two-holed Antimony Rubber Stopper to fit above chimneys (K 43)	6515	ea.	.65	.65
1 Nickel-plated Cup (Calorimeter)	66–65	ea.	.90	.90
2 pkgs. Picture Cord	90–75	pkg.	.10	.20
4 oz. Spring Brass Wire #27	90–45*c*	lot	.65	.65
4 oz. Iron Wire #27	90–70*b*	lot	.35	.35
1 Spool Piano Wire #9	57–12*b*	spl.	.12	.12
1 Spool Piano Wire #5	57–12*d*	spl.	.15	.15
1 Yard and Meter Stick	11–10	ea.	.45	.45
				$47.20

Electrical Supplies

3 lb. Copper Annunciator Wire	90–15	lb.	$1.25	$3.75
1 1-oz. Spool Copper Wire, bare No. 30	90–10	ea.	.20	.20
2 One-point Switches	90–340	ea.	.28	.56
4 Miniature Lamp Receptacles		ea.	.12	.48
4 Miniature Lamp Bulbs 2–4 volts		ea.	.25	1.00
1 Single-pole, Single-throw Knife Switch	90–325	ea.	.90	.90
1 sq. ft. Sheet Zinc		sq. ft.	1.25	1.25
1 sq. ft. Sheet Copper		sq. ft.	2.00	2.00
1 sq. ft. Sheet Lead		sq. ft.	1.30	1.30
4 Dissectible Iron Box Bells	90–525	ea.	.90	3.60
1 Carbon Cylinder LeClanche Battery		ea.	1.25	1.25
2 Bar Magnets, $8 \times \frac{1}{2} \times \frac{1}{4}$″		ea.	.65	1.30
2 lb. Iron Filings, fine and clean	80–180	lb.	.25	.50
1 Magnetic Compass, 50 mm. diam.	81–78	ea.	.85	.85
1 Magnetic Needle	81–12	ea.	1.10	1.10
6 Wood Push Buttons	90–370	ea.	.20	1.20
1 Telegraph Key	98–100	ea.	2.50	2.50
1 Telegraph Sounder	98–15	ea.	3.75	3.75
1 St. Louis Motor (Central Scientific Co., Chicago)	3745	ea.	5.00	5.00
				$32.49

Hardware and Kitchen Utensils

Purchase in the local Department, Hardware, and Notion Stores. It is recommended that a good quality be selected. Pupils will be able to supply some of the items.

1 Dish Pan
6 Teaspoons
1 Large Knife, bread knife
4 White Soup Plates
1 White Bowl, large size
1 Ice Cream Freezer
1 Ice Chipper or Shave
1 Ice Pick
1 One-gallon Bottle
1 Tin Quart Measure
1 Tin Gallon measure
1 pkg. Large Carpet Tacks
½ doz. Drinking Glasses
4 Milk Bottles, quart
2 Two-quart Agate Ware Kettles
4 White Dinner Plates
1 Lemon Grater
2 Tablespoons
2 Two-quart Shallow Pans (agate ware)
1 Kerosene Lamp, medium large
2 Tall Lamp Chimneys
12 Spikes, 5 inch
½ lb. Iron Wire Nails
1 Box Assorted Screws (small and medium)

1 Medium Screw Driver
1 Small Screw Driver
1 Monkey Wrench (small)
2 Lightning Seal Jars, 1 pint
2 Lightning Seal Jars, 1 quart
1 Side Cutting Pliers
1 Claw Hammer
1 Bicycle Pump
1 Lift Pump, commercial
1 Package Rubber Rings to fit jars

Miscellaneous Supplies

Purchase locally. Pupils will be able to supply some of the items.

1 Bottle Red Ink
1 Bar Castile Soap
5 lb. Coarse Salt
2 lb. Table Salt
1 Bottle Gasoline
1 lb. Can Baking Soda
1 Spool Silk Thread
1 Bottle Carbona
1 Bottle Liebig's Beef Extract
2 Cans Lye (concentrated)
1 C. E. Z. Gas Lamp with three extra mantles
1 Junior Welsbach Burner, with two extra mantles
4 oz. Soap Powder
1 lb. Crisco
1 Lot Diamond Dyes for Wool
1 Lot Diamond Dyes for Cotton
1 lb. Washing Soda
1 lb. Granulated Sugar
1 lb. Wheat Flour
1 Bottle LePage's Glue
1 Roll Absorbent Cotton
1 Can Karo Corn Sirup
1 yd. Cheesecloth

Lists of Special Apparatus

Desirable, but not essential. May be omitted, if considered too expensive.

1 Steel-bearing Harcourt Trip Scale (L. E. Knott)		15–160	$15.40
1 Aneroid Barometer	"	45–40	8.50
1 Mason's Wet & Dry Bulb Hygrometer	"	47–15	5.75

Essential Apparatus for schools not supplied with illuminating gas. The following apparatus will be found satisfactory and adequate.

1 Glass Alcohol Lamp 8-oz. (L. E. Knott)		5570*b*	$.60
1 Hot Blast Alcohol Stove	"	60–120	.45
1 Gasoline Blast Lamp	"	3687	8.25

(This lamp has a very hot flame. It is perfectly safe to use. Essential for bending glass tubing, etc.)

A compound Microscope is a valuable addition. The following instrument will be found satisfactory for Elementary School purposes.

1 Compound Microscope (L. E. Knott)		5870	$23.50
1 doz. Glass Slides	"	5990	.50
50 Circular Cover Glasses	"	5985*b*	.30

Dry Cells. Purchase dry cells from local garage or hardware store, as needed. They deteriorate rapidly. Be sure they are new. Have them tested. They should test from 25 to 30 amperes each.

Lime Water. Make your own lime water as follows: Put four lumps of unslaked lime, the size of a hen's egg, into a pan. Add one quart of cold water. The hard lumps will break up and the water will become hot. Let cool. Pour the mixture into a gallon bottle. Add cold water until the bottle is filled. Stopper tightly. Let stand overnight. The lime settles to the bottom of the bottle, leaving clear lime water above it. Siphon off the clear lime water, as needed. Refill bottle with water and shake. The bottle may be refilled with water many times before a new lime mixture is needed. Purchase unslaked lime from a hardware store, or a local dealer in lime and cement.

MINIMUM EQUIPMENT

The foregoing lists cover every experiment in the book, and make a very generous allowance for breakage. By omitting a few problems, and using care in the matter of breakage, a great saving can be made in the cost of equipment. This may be desirable if sufficient funds are not available to purchase the complete list of apparatus and supplies. No allowance has been made in this list for kitchen utensils and miscellaneous material. These may be brought from home or purchased at a local store.

The total cost of this minimum list will not exceed fifty dollars.

The list will be found adequate, however, if the following problems are omitted:

Problem 2 of Project I in Chapter III
Project V, entire, in Chapter III
Problem 2 of Project I in Chapter IV
Problem 2 of Project II in Chapter IV
Problem 1 of Project I in Chapter VI
Problem 3 of Project III in Chapter VI
Project III, entire, in Chapter VII
Project IV, entire, in Chapter VIII

With these omissions, the course will still be found adequate for a year's work, and all of the remaining problems can be taught in an ordinary classroom, without gas or running water. A few dry cells will furnish the needed electric current. In ordering the following equipment it will be well to consult the preceding lists. Catalog numbers are those of the Knott Apparatus Company.

Chemical Apparatus

2 Glass Beakers, 400 cc.
4 Erlenmeyer Flasks, 500 cc.
1 Glass Funnel, 4 in.
2 Glass Bottles, Wide-mouth, ½ pint
2 lbs. Glass Tubing, ¼ in.
8 oz. Capillary Tubing, 1 mm. bore
12 Glass Petri Dishes, 4 in.
1 Triangular File

1 Steel Forceps
2 pcs. Iron Gauze with Asbestos center
1 Box Gummed Labels
1 pkg. Filter Paper, 4 in.
1 Wooden Test Tube Rack
10 ft. Antimony Rubber Tubing, $\frac{5}{16}$ in.
10 ft. Antimony Rubber Tubing, $\frac{1}{4}$ in.
1 Test Tube Clamp
2 Thistle Tubes, 10 in.
$\frac{1}{2}$ Gross Test Tubes, 6 × 1 in.
2 Two-hole Antimony Rubber Stoppers (K 28)
2 One-hole Antimony Rubber Stoppers (K 28)
1 Solid Antimony Rubber Stopper (K 28)
2 One-hole Antimony Rubber Stoppers (K 25)
2 Two-hole Antimony Rubber Stoppers (K 30)
1 One-hole Antimony Rubber Stopper (K 30)

Chemicals and Reagents

3 lbs. Hydrochloric Acid
3 lbs. Nitric Acid
4 lbs. Sulphuric Acid
1 lb. Ammonium Chloride
4 oz. Agar Agar
8 oz. Carbon Bisulphide
1 lb. Copper Sulphate, crystals
1 lb. Ether
$\frac{1}{2}$ gal. Alcohol, denatured
1 pkg. Fehling's Solution Tablets
1 oz. Iodine, resublimed
1 oz. Lycopodium Powder
4 oz. Manganese Dioxide, powdered
2 lbs. Marble Chips
1 oz. Magnesium Powder
1 lb. Mercury
4 oz. Malt, ground (raw)
2 oz. Phosphorus, yellow, sticks
8 oz. Potassium Chlorate, crystals
4 oz. Potassium Iodide
8 oz. Sulphur Flowers
1 lb. Zinc, granulated (mossy)

Physical Apparatus

1 Rubber Bag, 43–230
1 Sensitive Hand Balance, 15–200
2 Ring Stands, large, 6691 *c*
2 Open Side Rings, 4 in., 6461 *c*
1 Barometer Tube, 41–155
1 Fahrenheit Chemical Thermometer, 63–56
2 Lamp Chimneys, 61–161
1 Glass Alcohol Lamp, 8 oz., 5570 *b*
1 Hot Blast Alcohol Stove, 60–120

Electrical Supplies

1 lb. Copper Annunciator Wire, 90–15
3 Iron Box Bells, 90–525
1 Carbon Cylinder Leclanché Battery
1 St. Louis Motor (Central Scientific Co., Chicago, 3745)
2 Bar Magnets, 8 × $\frac{1}{2}$ × $\frac{1}{4}$ in.
1 lb. Iron Filings, fine
3 Wood Push Buttons

INDEX

Acid cell, 261
  action of, 262
Adulteration of cloth, 330–331
  of foods, 58
Agar, 354
Air, 2–22
  circulation of, 117
  cold air heavier than warm, 116
  composition of, 5, 20
  has weight, 3
  occupies space, 2
  pressure, 111
  primary in gas burners, 233
  quantity breathed out, 11
  secondary, 233
  varying pressure, 112
  water vapor in, 121, 122
Alcohol, 150
Ammeter, 296
Ammonia formed in wet cell, 263
Ammonium chloride in wet cell, 262, 295
Amperes, 296
Aneroid barometer, 113
Anthrax, 372
Armature poles change, 283–284
Artificial ice, 139
Ash in milk, 36
Atmosphere, weight of, 136

Bacillus, 348
Bacteria, 347–365, 369–376
  and decaying teeth, 359–360
  and disease, 352–353, 370, 372
  and the house fly, 357–358
  forms of, 347–349, 369
  how they multiply, 349, 369–370
  how to kill, 362–365, 375
  in drinking water, 360
  in dust, 355
  in milk, 351–352, 361
  on hands, 357
  rate of increase, 349–350, 370
  scattered by coughing and sneezing, 358–359
  size of, 347
  spoil food, 351–352
  work of, 351–353
Bacteria gardens, 354–361, 374
  how to prepare, 354–355
Barometer, 111–114
  invention of, 136
Batteries, electric, 261, 262, 264
Bell systems, 275–277
Boiling water, 73, 103
  temperature of, 73, 75, 103
Bread mold, 343, 345
Bread, raising of, 340–341, 367–368
Bread toaster, 293
Bread, water in, 10
Breathing, 10–13, 19–21
Bulbs, wet and dry, 124
Bunsen burner, 205–206, 218
Burning, products of, 159, 160, 161, 163, 180

Candle, 220–222, 253
  how it burns, 220, 253
  how it gives light, 221, 253
  results of burning, 221–222
Carbon, 30
  how leaves get, 31
  in dry cells, 264, 265
  in starch, 29
  product of burning, 31
Carbon dioxide, 7, 18, 31
  effect on fire, 158
  in air, 9
  in breath, 10

Carbon dioxide (*Continued*)
in fire extinguishers, 172, 173
test for, 9
Carbon monoxide, 164, 217
Carbon tetrachloride, 174, 181
Carbona, 325
Centigrade scale, 110
Cerium, 234, 255
C. E. Z. burner, 231
Cloth
how to test, 312–314
how woven, 308–311
kinds of, 306, 307
Clothes, 305–333
how to wash, 315, 331–332
Clouds, 140–143
Coal
hard, 146, 175
how it burns, 163
products of burning, 163
soft, 147, 175
Coccus, 348
Cocoon, silk, 327
Coke, 148, 175, 217
Cold storage, 139
Combustion, results of, 159, 160, 161, 163, 180
Compass, how to make, 270, 297
Condensation, 128, 139
Conduction, 183, 212
Conductor, 265
Constipation, 56
Convection, 184–186, 193, 213
Copper plating, 287–289, 302
Cost of gas, 238
Cotton, 306, 326, 329, 330, 331
how to test, 313, 330
Coughing scatters bacteria, 358–359

Decaying teeth and bacteria, 359
Demonstration board for wiring, 275
Dew, 129, 142
Dew point, 129
Diastase, 33
Digestion, 49–52, 56
organs of, 52
Disinfectants kill bacteria, 364
Distillation, 79
Draft, 154, 177
cause of, 117
Dry cell, 264, 296
parts of, 264–265
Dust, 19
carries disease, 355
explosion of, 168
Dyeing, 320–322, 332

Edison, Thomas A., 256
Electric bells, 273–277, 298
how it rings, 273–275, 298
how to connect, 275–277
parts, 273, 274
Electric cells, 261–266, 295–296
Electric fuse, 245, 246
Electric lamp, 240, 256–257, 304
how it burns out, 242
how it gives light, 241
Electric light, 240–249
Electric meter, 247–249
Electric motor, 280–286, 300
how it runs, 285, 301
how poles of armature change, 283–284, 301
parts of, 280
Electric plating, 287–289, 302
Electric switches, 245, 246
Electric wiring, 243–247
Electricity, 259–304
by chemical action, 262–266
from rubbing, 260, 295
how it is stored, 290, 303
how it produces heat, 292–294, 304
how it produces light, 304
how it produces motion, 282, 302
Electricity, cost of, 248
Electro-magnet, 271–272, 297–298
Enzymes, 368
Equipment for laboratory, 383–389
Evaporation, 121, 138
affected by heat, 122, 138
affected by wind, 122, 138
cooling effect of, 123, 138
of ether, 123
freezing by, 123, 139

Explosion, of dust, 168
of gasoline, 166
of illuminating gas, 167

Fahrenheit scale, 110
Fats in foods, 35, 46, 54
Fehling's solution, 33, 36, 49
Fermentation, 335, 366–367
Filtration, 77, 78, 104
Fire, 145–181
dangers from, 165–170
how to check, 157, 178
how to kindle, 151, 153, 176
how to put out, 171–174
how to regulate, 156, 157, 178
how water puts out, 171, 180
starts itself, 165
Fire extinguisher, 171–173, 180
Fire prevention, 169–170, 180
Flame, 159, 164
of Bunsen burner, 204–207
Flies and disease, 357–358
Focus, 252
Fog, 141
Food, 23–58
absorption of, 51
adulteration of, 58
ash in, 36
burns, 44–46
buying, 57
composition of, 35–42
diagrams, 41, 42
fat in, 35, 37, 46, 54
how to keep from spoiling, 369, 371
kinds of, 34
muscle building, 43, 54
spoiled by bacteria, 351–352
spoiled by molds, 368–369
starch in, 37–38
sugar in, 37, 53
tables, 40
testing, 37–38
uses of, 43–47
variety needed, 54
water in, 38
Freezing, 66
by evaporation, 123
Frictional electricity, 260, 295
Fuels, 146–150, 175
Furnace, 189
Fuse, 245, 246

Galileo, 136
Galvani, 295
Gas, composition of, 204, 217
cost of, 238
economy of, in cooking, 210–211, 218
how it burns, 205–207
how made, 201
illuminating, 201–211, 217
peculiarities of, 202
Gas explosion, 167
Gas in candle flame, 220
in lamp flame, 226–227
Gas lamps, 230–236, 255
to adjust, 235
C. E. Z., 231
how they give light, 233
inverted, 232
parts, 230, 232
Gas mantle, 234, 255
Gas measurement, 236–238
Gas range, 208–210
Gasoline, 149
danger of, 166
how to extinguish, 174, 181

Heat, absorbed by dull objects, 187
effect on air, 115, 116, 117, 154
effect on water, 71
given off by dull objects, 188
in steam, 199
travels by conduction, 183, 212
by convection, 184–186, 213
by radiation, 186, 213
Heat by electricity, 292
Heat kills bacteria, 362
Heating, 182–218
by hot air, 189–191, 214
by hot water, 192–196, 214
by steam, 197–200, 215
Heating systems, care of, 215, 216
Hoffman's apparatus, 63

Hot air heating, 189–191
Hot water heating, 192–196
Hot water heating model, 193
Humidity, relative, 125
  table, 126
Hydrogen, 60, 65, 101
  burns, 61
  in electric cells, 262, 263, 264, 296
  weight of, 62
Hygrometer, 124, 127

Ice, 66–72, 101–102, 139
  in refrigerator, 69
  melting, 71
Ice cream, 67, 68
Illuminating gas, 201–211, 217, 236–239
  cost of, 238
Incandescence, 235
Insulator, 265
Iodine in starch test, 26
Iodine kills bacteria, 364
Iron burns in oxygen, 5

Javelle water, how to make, 324, 333

Kerosene, 149
  products of burning, 227
Kerosene lamp, 223–229
  care of, 228–229
  how it burns, 223
  how it gives light, 226
  parts of, 223, 224
Key, telegraph, 278, 299
Kilowatt hours, 247
Kindling temperature, 152, 153, 176
Koch, Robert, 372

Lamps, electric, 240–242, 256–257, 294
Lamps, gas, 230–236
  C. E. Z., 231
  how they give light, 233
  inverted, 232
  parts, 230, 232
  to adjust, 235
Lamps, kerosene, 223–229, 254
  care of, 228–229
  how they burn, 223
  how they give light, 226
  parts of, 223, 224
Leaves as starch makers, 28, 53
Lens, 252
Library for General Science, 380–382
Light, and temperature, 250
  artificial, 253
  reflection of, 251
  refraction of, 252
Lighting of homes, 230–258
  direct and indirect, 258
  with electricity, 240–249
  with gas, 230–239
Lime water, 9
Linen, 326
  how to test, 313, 331
Lines of force, 268
Liquid fuels, 149
Lungs, capacity of, 12, 20
Lycopodium powder, 168

Magnesium, burning, 161
Magnets, 267–272, 296–297
Manganese dioxide, in dry cell, 265
  in making oxygen, 4
Mantle, gas, 234, 255
Mason's hygrometer, 127
Matches, 152
Mazda lamps, 304
Meter, electric, 247–249
Meters, how to read, 95–96, 237
Microns, 347
Microscopic organisms, 366
Milk, composition of, 35–37
  pasteurized, 58, 361
Molds, 342–346, 368
  conditions of growth, 344–345
  different molds, 345–346
  how they multiply, 344
  raising molds, 343
  where they come from, 342
Moldy bread, 343, 345
Morse alphabet, 279
Muscle building foods, 43, 54

Nasturtium leaves, starch in, 26–29

Nichrome, 294
Nitrogen, 7, 18
Nutrient agar, 354–355

Oersted, 297
Osmosis, 49, 50
Oxygen, 4, 17, 65, 101
  how to prepare, 4

Paraffin, 149
Pasteur, Louis, 372
Pasteurized milk, 58, 361
Peat, 147, 175
Peptones, 56
Petroleum, 149
Phosphorus, 5, 151, 165
Poles of magnet, 268–270, 297
Potassium chlorate, oxygen from, 4
Pressure cookers, 75, 103–104
Primary air in gas lamps, 233
Projects, individual, 377–379
Protection against fire, 169
Protein, 36
  digestion of, 50
  in foods, 43, 44, 53
  test for, 36
Protoplasm, 347, 369
Ptomaine poisoning, 58
Pumps, 81–86
  force, 84–86
  lift, 82–84

Radiation, 186, 213
Rain, cause of, 129, 142
Raising bread, 340–341, 367–368
Ration for a day, 48
Reflection, 250–252
Refraction, 252
Refrigerator, 69
Relative humidity, 125, 139
  table, 126
Removing spots and stains, 322–325, 332–333
Resistance, electrical, 304

Sal ammoniac, in dry cell, 265
  in wet cell, 262, 295
Saliva, in digestion, 49, 50
Secondary air in gas lamps, 233
Silk, 327
  how to test, 313, 331
Silk worms, 327
Siphon, 87, 88
Smoke, 162, 178
Sneezing scatters bacteria, 358, 359
Snow, 142
Soap, how to make, 316–317
Soap suds, 318–319
Soot, 159, 204, 220, 229
Sounder, telegraph, 278, 299
Sparks, 159, 160
Spinning yarn, 308
Spirillum, 349
Spontaneous combustion, 165
Spots, removal of, 323–325, 332–333
Stains, removal of, 323–325, 332–333
Starch, changed to sugar, 32
  composition of, 29
  digestion of, 49
  from potato, 24
  in leaves, 26–28
Starting a fire, 153
Steam, engine, 76
  expansion of, 75
Steam heating, 197–200
Steam heating system, 199
Stomata, 53
Storage battery, 290–291, 303
Storms, route of, 133–134
Stoves, kitchen, 154, 155
Sugar, 37, 53
Sunlight kills bacteria, 362–363
Switch, electric, 245, 246

Tapeworm, 58
Telegraph set, 278, 299
Telephone, 299
Temperature, of boiling water, 73, 7
  kindling, 152, 153
Thermometer, 108–110
  scales, 110
Thorium, 234, 255
Thread, how spun, 308
Torricelli, 136

Transparency, 250
Trichina, 58
Tuberculosis, 22, 373
Tungsten filament in electric lamp, 240, 257, 304

Vane, 119
Vaseline, 149
Ventilation, 14–16, 21
Vitamines, 47, 55
Voltmeter, 296
Volts, 296

Warp, 309, 328
Washing clothes, 315, 331, 332
Water, bacteria in, 360–361
  boiling, 73, 103
  cold heavier than hot, 192
  composition of, 63–65, 101
  contamination of, 89, 105–106
  cost of, 95–97
  disease germs in, 105
  distillation of, 79
  distribution of, 91, 94
  filtration of, 77, 78, 104
  for Boston, 93–95
  for Lawrence, 104
  formed when wood burns, 160
  hard and soft, 317–319
  how it carries heat, 193
  how it puts out fire, 171, 180
  in leaves, 30
  least volume, 71
  meters, 95–96
  purification of, 77
  supplies, 89, 93–95, 105
  uses of, 100
  volume at different temperatures, 71, 102
  waste of, 97, 99
Water gas, 217
Water vapor, 19
  amount of, 140
  how measured, 124
  in air, 121, 138
  in breath, 10
  varies with temperature, 130, 140
Weather, 107, 144
  changes in, 142–144
  observations, 120, 135
Weather forecasting, 135
Weather maps, 131–133
  reading of, 131, 133
Weaving, 309–311, 327–328
Welsbach mantle, 234, 255
Wet cells, 262–264, 295
  action of, 262, 264
Winds, 115–119, 137
  direction of, 118
  vanes, 118
  why winds blow, 117, 137
Wiring board, 275
Wiring, electric, 243–247
Wood, as fuel, 148, 176
  as kindling, 152
  gas from, 160
  how it burns, 159
  products of burning, 159, 180
Woof, 309, 328
Wool, 326, 329, 330, 331
  how to test, 313, 330
World of little things, 334–376

Yarn, how spun, 308
Yeast, action of, 335–337
  conditions of growth, 338–341
  where it comes from, 338
Yeast plants, 335–341, 367
  how they multiply, 337–338

Zinc chloride formed in dry cell, 264
  in wet cell, 262, 263, 296